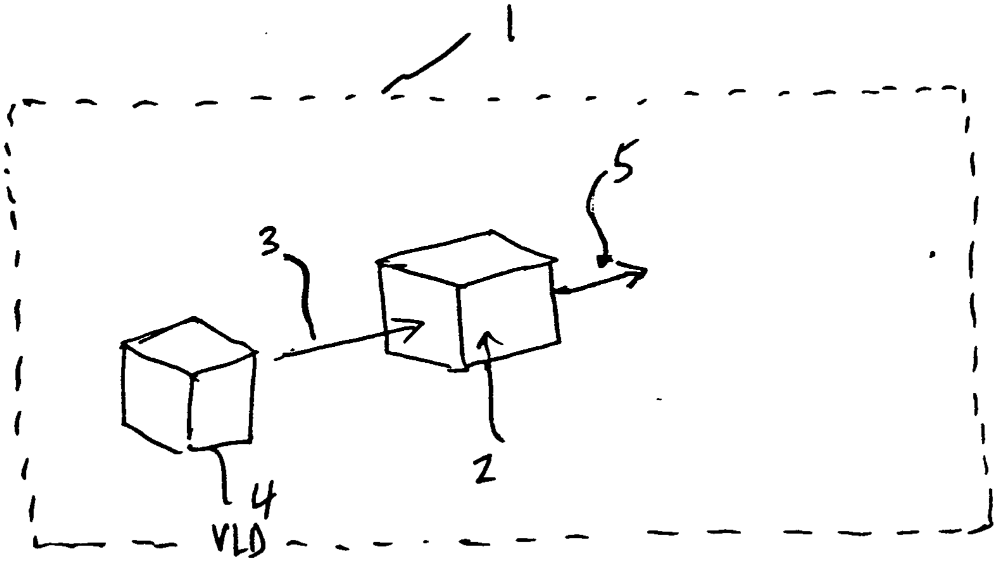


FIG. 1

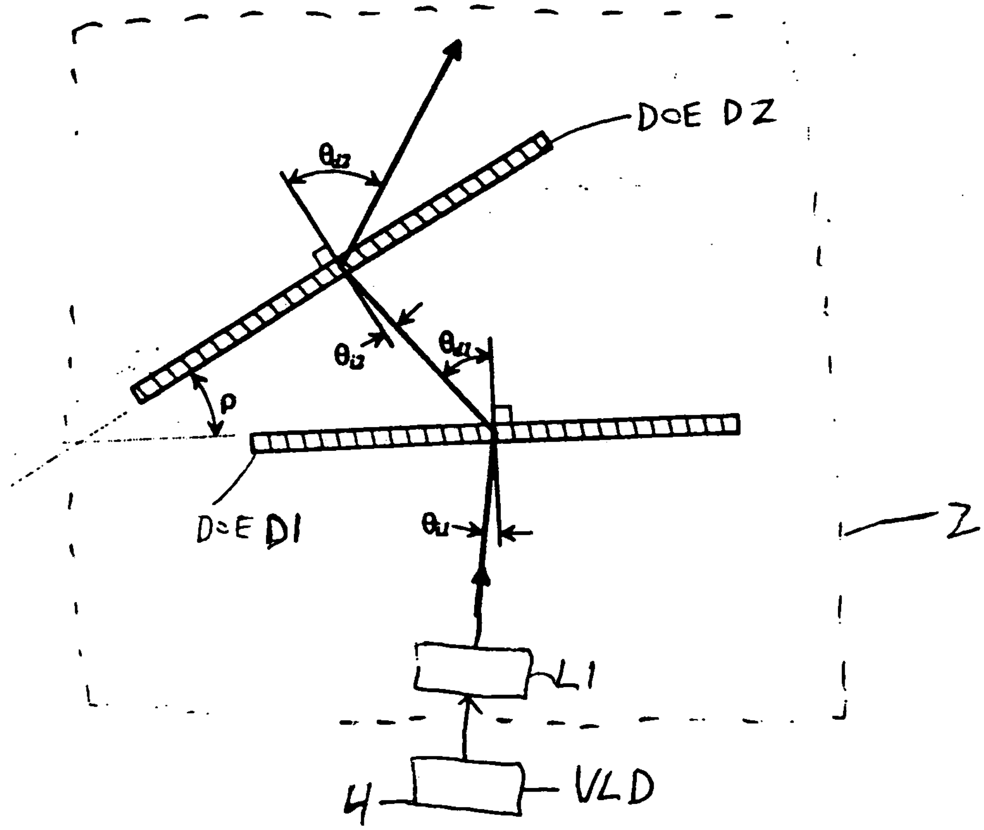


FIG. 1A

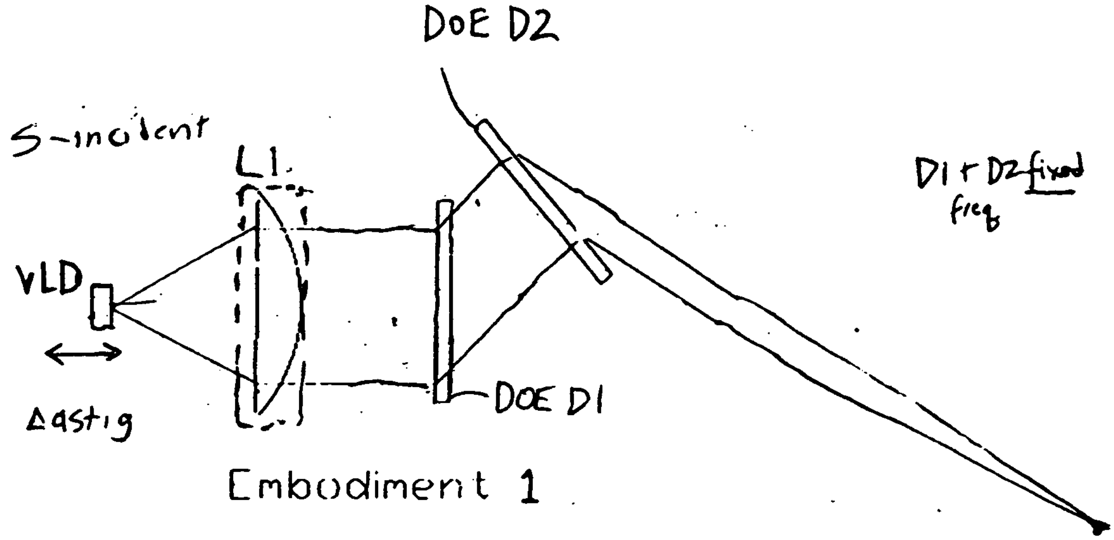

DOE D2
S-incident
L1
VLD
Δastig
DOE D1
D1 + D2 fixed freq
Embodiment 1

FIG 2A

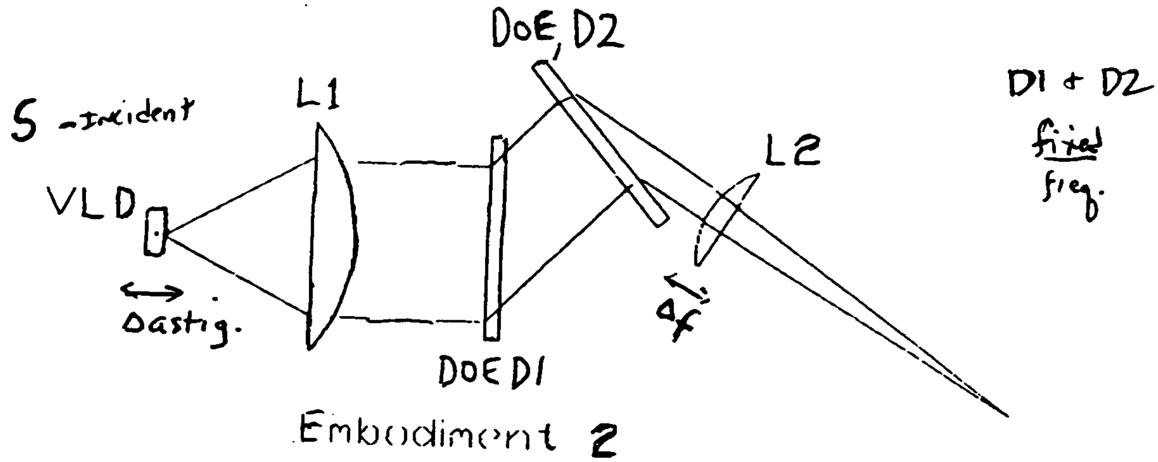

DOE, D2
D1 + D2
fixed
freq.
S-Incident
L1
L2
VLD
Δastig.
Δf
DOE D1
Embodiment 2

FIG. 2B

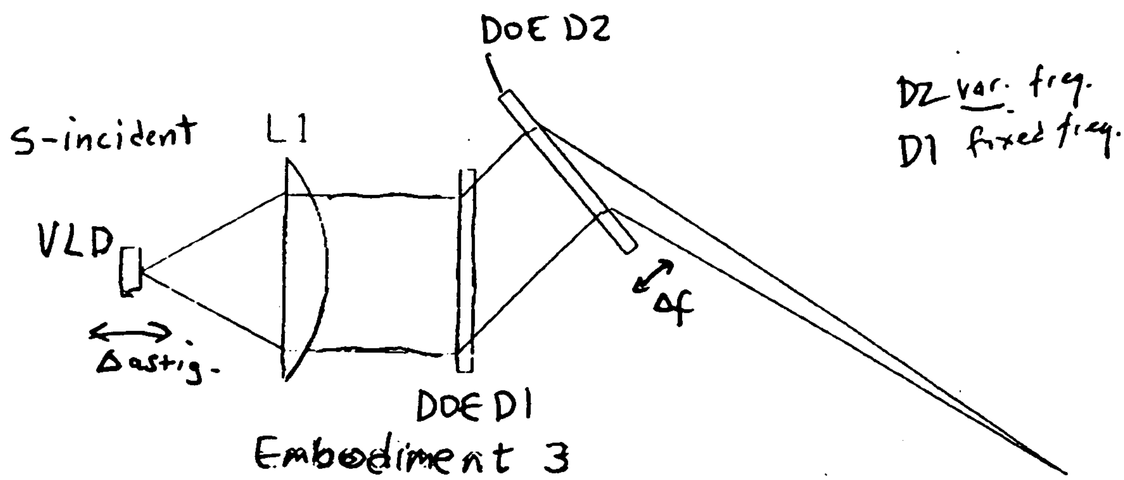
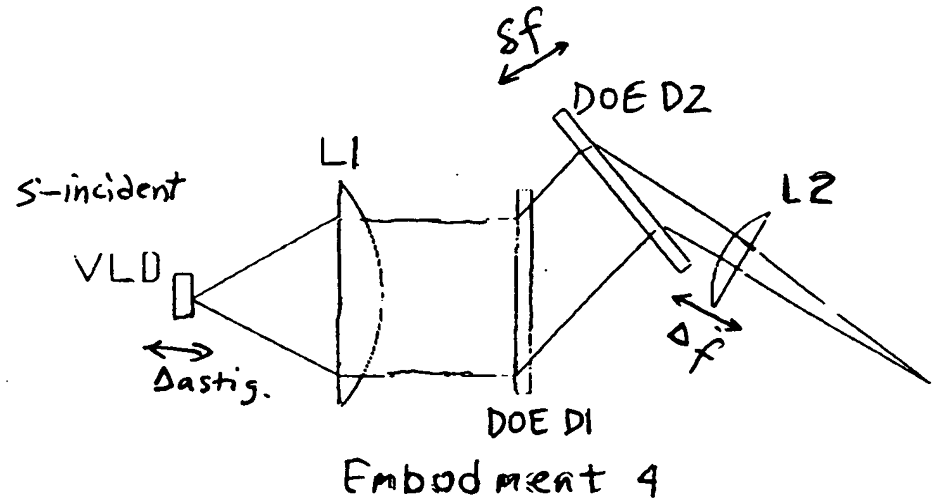
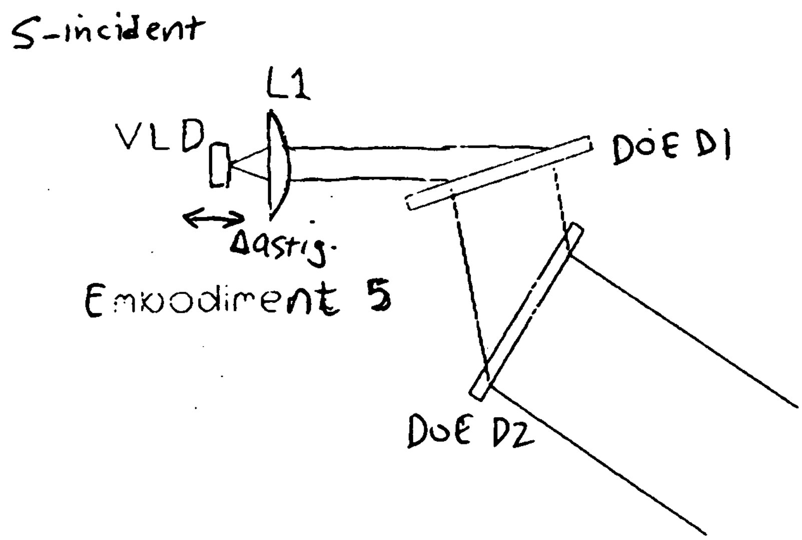

DOE D2
D2 var. freq.
D1 fixed freq.
S-incident
L1
VLD
Δastig.
Δf
DOE D1
Embodiment 3

FIG. 2C



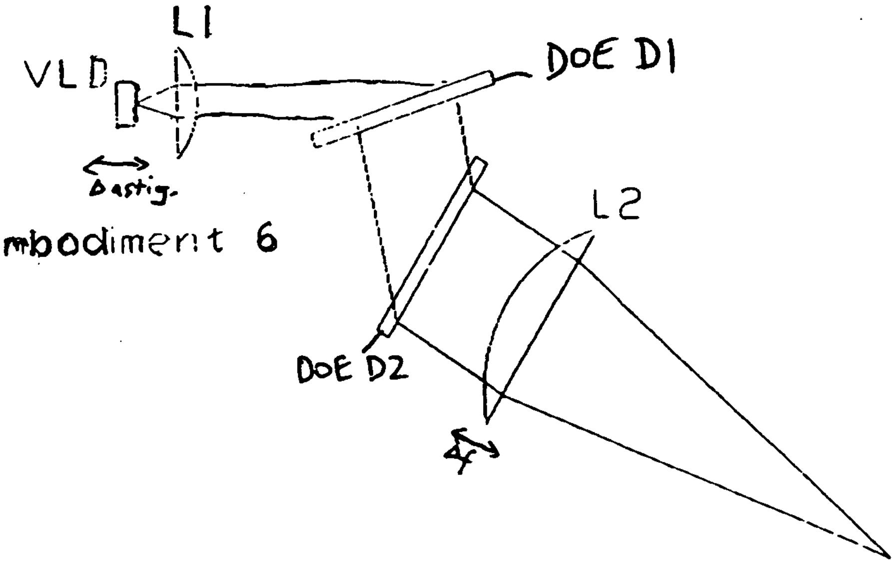
D1 fixed freq
D2 var. freq

FIG. 2D



D1 + D2
fixed freq

FIG. 2E

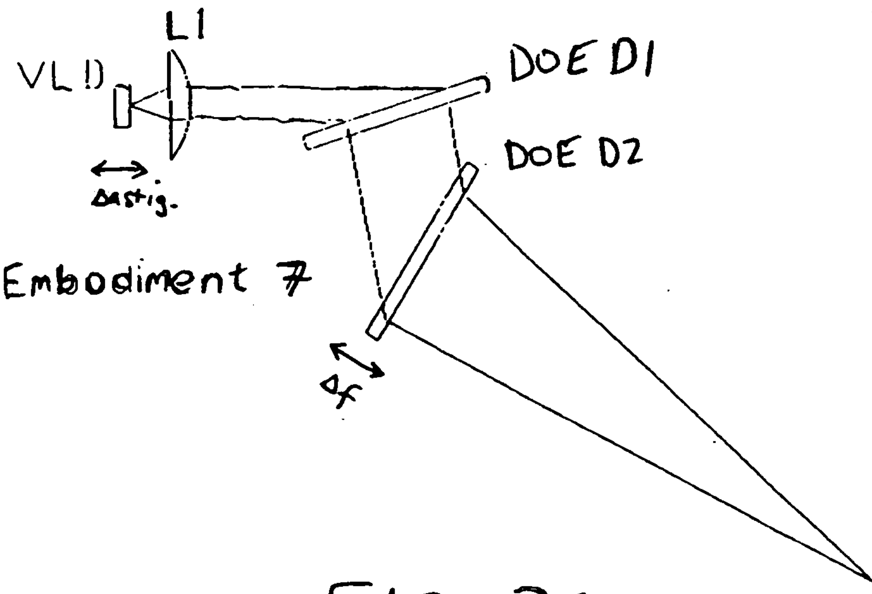


Embodiment 6

D1 & D2 fixed freq.

FIG. 2F

~~Embodiment~~



Embodiment 7

D1 fixed freq.
D2 var. freq.

FIG. 2G

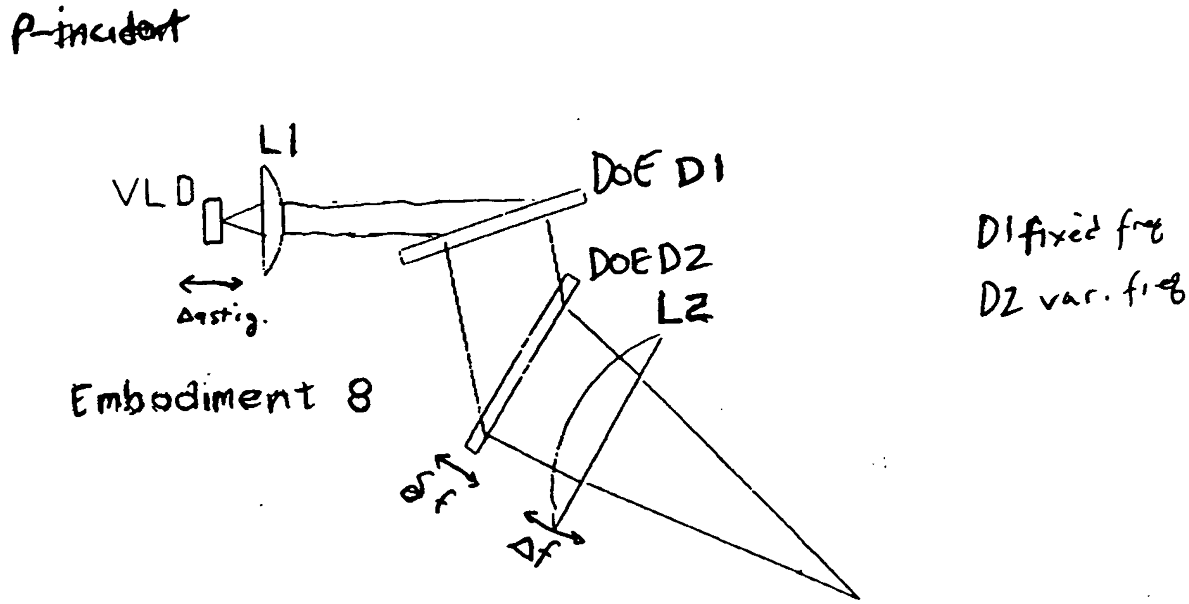

p-incident
L1
VLD
DOE D1
DOE D2
L2
Δastig.
Embodiment 8
δf
Δf
D1 fixed frq
D2 var. freq

FIG. 2H

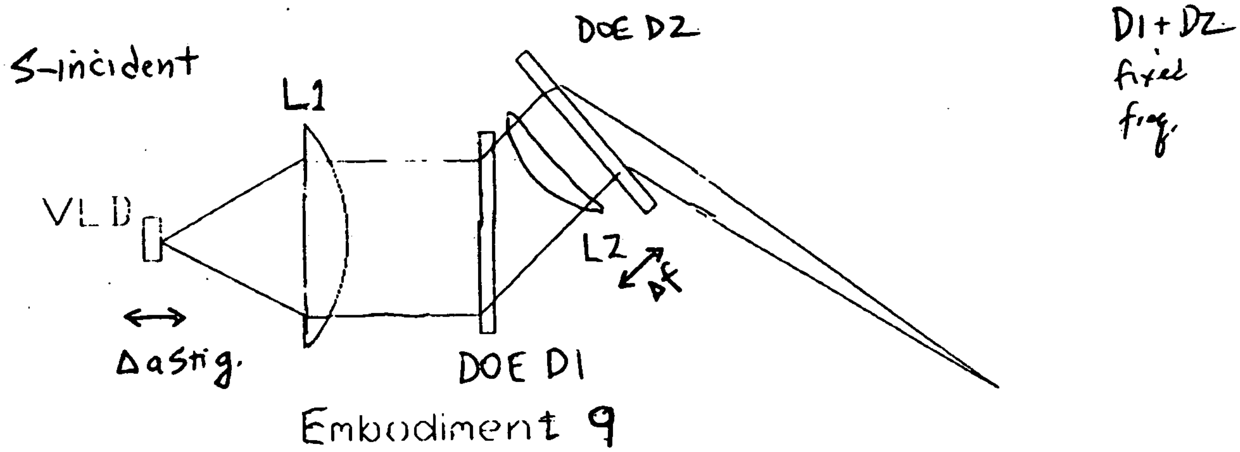

S-incident
L1
VLD
DOE D2
L2
Δf
Δastig.
DOE D1
Embodiment 9
D1 + D2
fixed
frq.

FIG. 2I

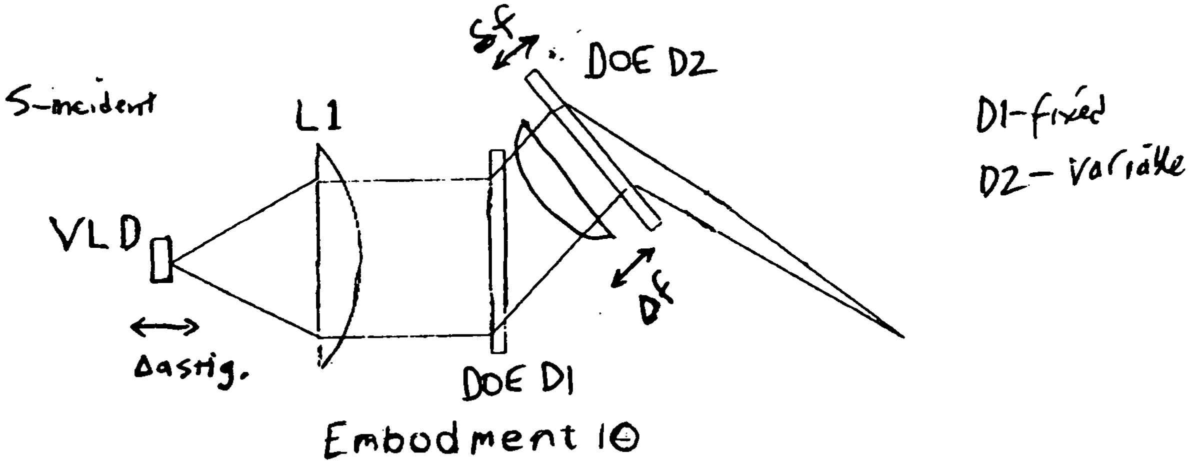

DOE D2
S-incident
L1
D1-fixed
D2- variable
VLD
Df
Δastig.
DOE D1
Embodment 10

FIG. 2J

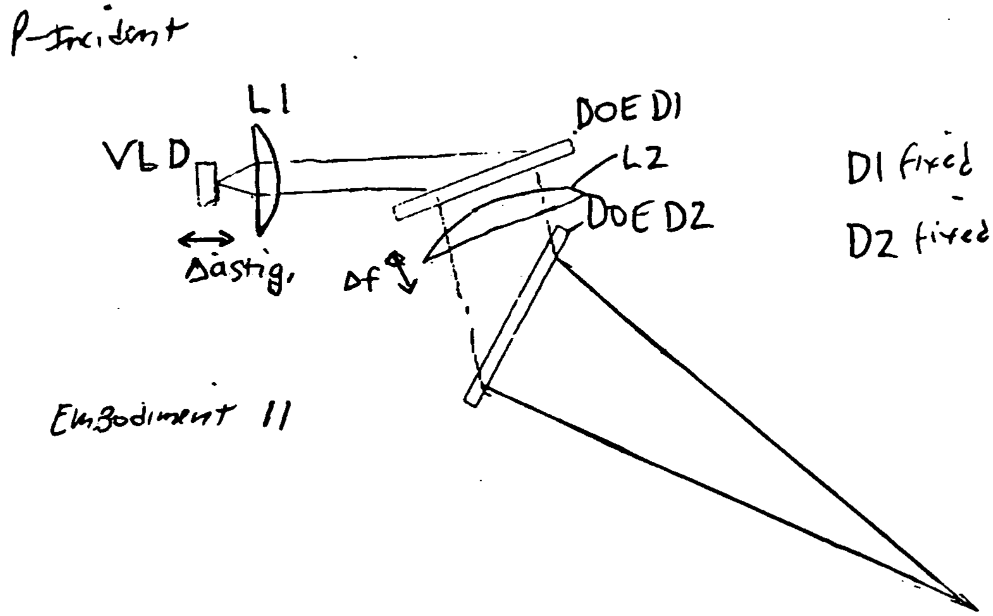

P-Incident
L1
DOE D1
VLD
L2
D1 fixed
DOE D2
D2 fixed
Δastig.
Df
Embodiment 11

FIG. 2K

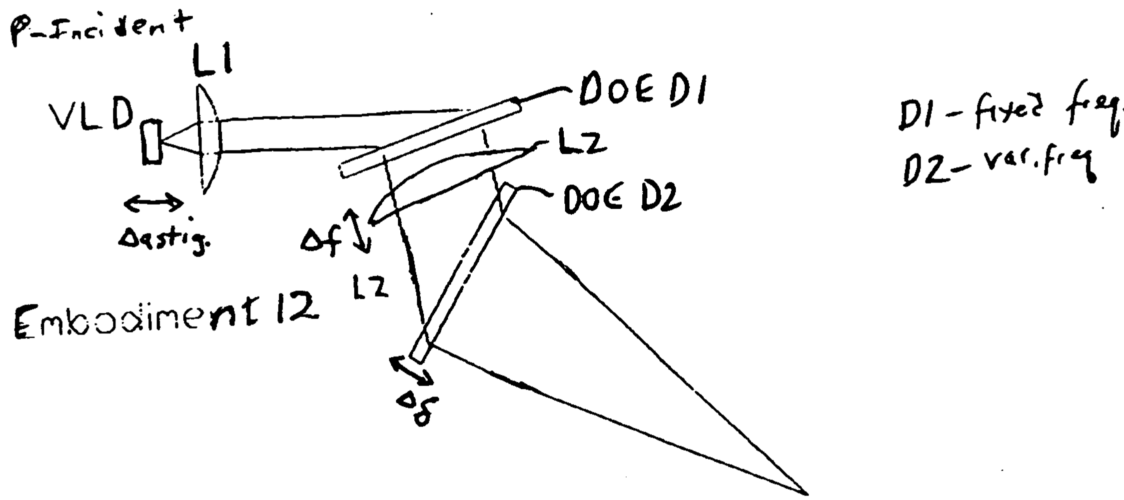
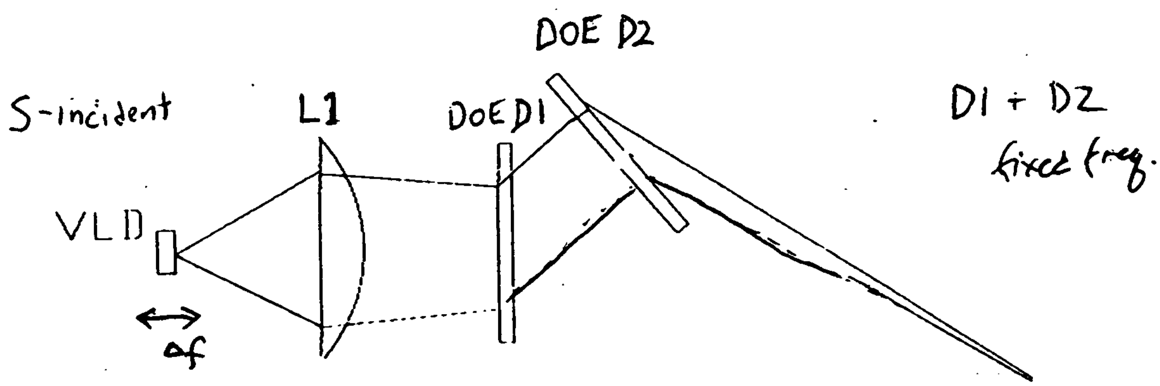


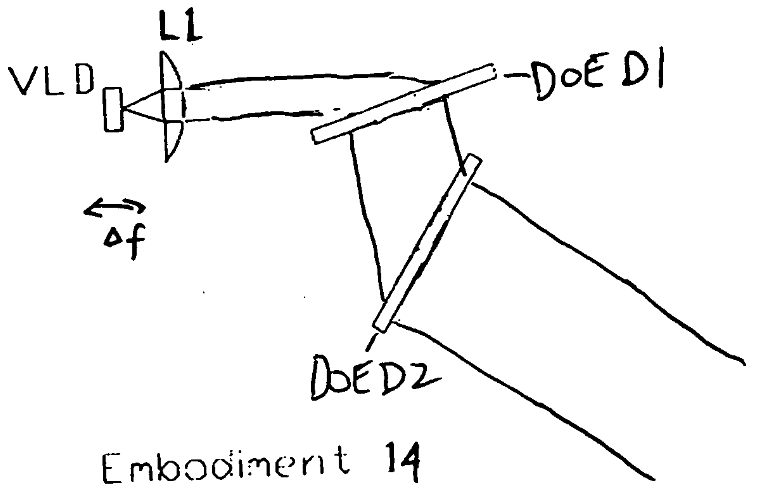
FIG. 2L



Embodiment 13

FIG. 2M

θ-incident



D1 & D2 fixed freq.

FIG. 2N

Establish End-User Requirements for Laser Beam Producing Module Under Design (eg. working distance, depth of field, bar code resolution, etc.) — A

↓

Determine the necessary spot-size, aspect-ratio, and waist dimensions of the output laser beam in order to scan the desired class of bar code symbols — B

↓

Determine the focal distance of the laser beam producing module (i.e. system) module which provides the desired depth of field for the end-user scanning system at the desired working distance — C

↓

Using the Gaussian beam propagation model, determine the required beam size and aspect Ratio Leaving The Laser Beam producing system under design — D

↓

(A)

FIG. 3A1

A

Choose a laser source (eg VLD) having acceptable beam characteristics and an acceptable amount of beam astigmatism — E

Determine an appropriate value for the Beam Shaping Factor of the HOE-based laser beam modifying subsystem (i.e. DOE D_1 and DOE D_2) in order that the aspect-ratio of the laser beam entering the subsystem will leave the subsystem with the aspect-ratio determined at Block D. — F

Use the Beam shaping Factor determined at Block F to determine the HOE construction parameters ($\theta_{O1}, \theta_{R1}, \theta_{O2}, \theta_{R2}, \rho$) expressed at Reconstruction wavelength λ_R for DOEs D1 and D2, so that the output laser beam has zero net dispersion and the desired aspect ratio determined at Block B — G

B

FIG 3A2

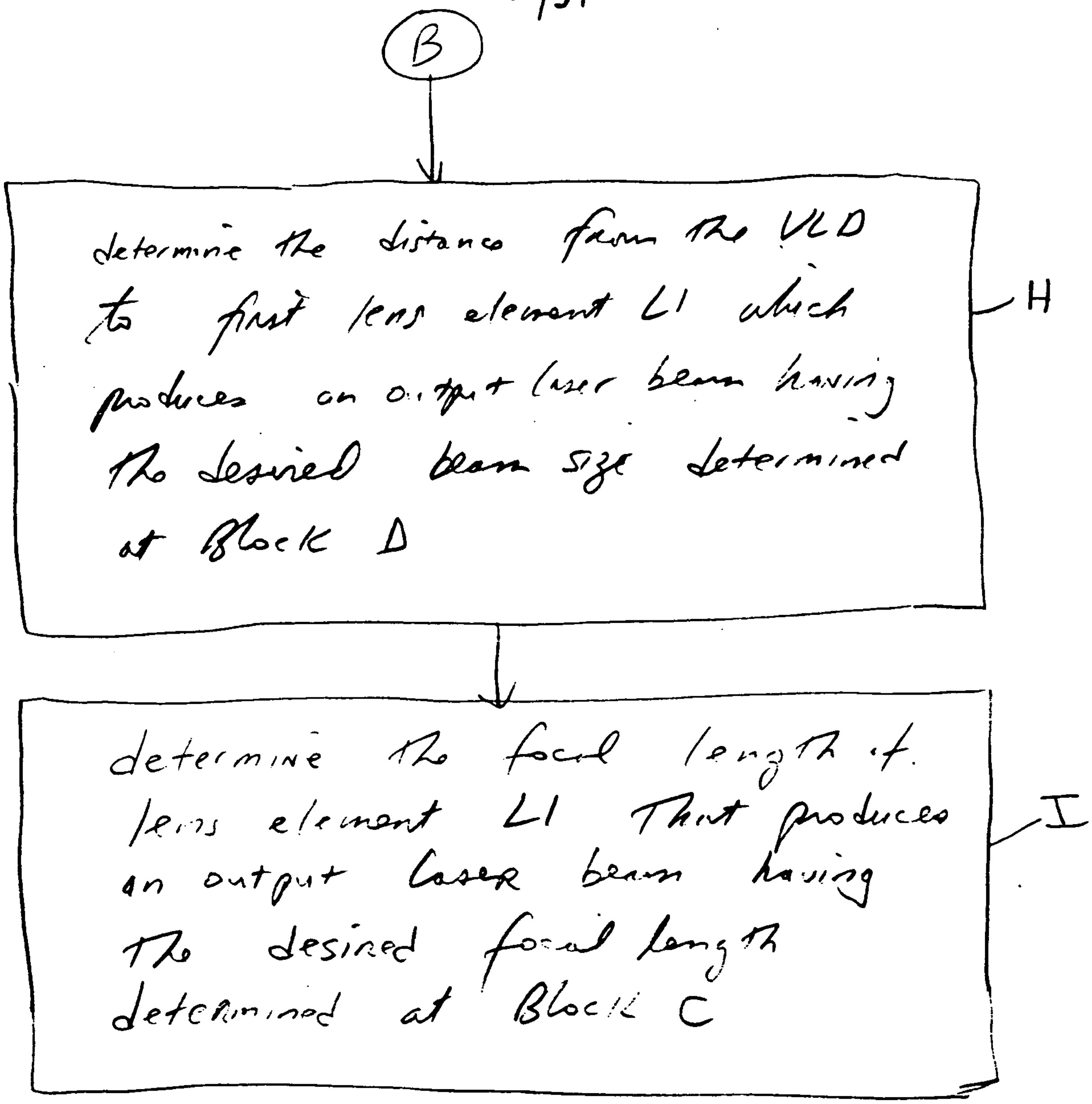

B
determine the distance from the VLD to first lens element L1 which produces an output laser beam having the desired beam size determined at Block D
H
determine the focal length of lens element L1 that produces an output laser beam having the desired focal length determined at Block C
I

FIG 3A3

Establish End-User Requirements For Laser Beam Producing Module Under Design (eg. working distance, depth of field, bar code resolution, etc) — A

↓

Determine the necessary spot-size, aspect-ratio, and waist dimensions of the output laser beam in order to scan the desired class of bar code symbols — B

↓

Determine the focal distance of the laser beam producing module (i.e. system) module which provides the desired depth of field for the end-user scanning system at the desired working distance — C

↓

Using the Gaussian beam propagation model, determine the required beam size and aspect Ratio Leaving The Laser Beam producing system under Design — D

↓

(A)

FIG. 33I

(A)

Choose a laser source (eg. VLD) having acceptable beam characteristics and an acceptable amount of beam astigmatism — E

Determine an appropriate value for the Beam Shaping Factor of the HOE-based laser beam modifying subsystem (i.e. DOEs D1 + D2) in order that the aspect-ratio of the laser beam entering the subsystem will leave the subsystem with the aspect-ratio determined at Block D. — F

Use the Beam Shaping Factor determined at Block F to determine the HOE construction parameters (Θ_{01}, Θ_{R1}, Θ_{02}, Θ_{R2}, P) expressed at reconstruction wavelength λ_R for HOEs H1 and H2, so that the output laser beam has zero net dispersion and the desired aspect ratio determined at Block B — G

(B)

FIG. 3B2

B

H — determine the distance from the VLD to first lens element L1 which produces an output laser beam having the desired beam size determined at Block D

I — Determine which optical component of the system will converge/divergence the laser beam from the VLD so that upon adjusting the separation between the VLD and Lens L1, the convergence or divergence of the non collimated laser beam entering the ~~DOE~~-based subsystem cancels out the inherent astigmatism in the beam produced by inherent characteristics of the VLD.

J — Determine the optical parameters in the laser beam producing system under design to yield the desired focal distance in the output laser beam determined at Block C

FIG. 3B3

Establish End-User Requirements for Laser Beam Producing Module Under Design (eg. working distance, depth of field, bar code resolution, etc) — A

↓

Determine the necessary spot-size, aspect-ratio, and waist dimensions of the output laser beam in order to scan the desired class of bar code symbols — B

↓

Determine the focal distance of the laser beam producing module (i.e. system) module which provides the desired depth of field for the end-user scanning system at the desired working distance — C

↓

Using the Gaussian beam propagation model, determine the required beam size and aspect ratio leaving the laser beam producing system under design — D

↓

A

FIG. 3C1

A

Choose a laser source (eg. VLD) having acceptable beam characteristics and an acceptable amount of beam astigmatism — E

Determine an appropriate value for the Beam Shaping Factor of the HOE-based laser beam modifying subsystem (i.e. DOEs D1 & D2) in order that the aspect-ratio of the laser beam entering the subsystem will leave the subsystem with the aspect-ratio determined at Block D. — F

Use the Beam Shaping Factor determine at Block F to determine the HOE construction parameters ($\theta_{O1}, \theta_{R1}, \theta_{O2}, \theta_{R2}, \rho$) expressed at reconstruction wavelength λ_r for DOEs D1 and D2, so that the output laser beam has zero net dispersion and the desired aspect ratio determined at Block B — G

B

FIG. 3C2

B

determine the distance from the VLD to first lens element L1 which produces an output laser beam having the desired beam size determined at Block D — H

determine the focal length of lens L1 so that, when the correct amount of seperation exists between the VLD and lens L1, the resulting covergence/divergence of the laser beam will eliminate astigmatism upon passing through DOE D1 only. — I

Assume HOE H2 is a stigmatic-type optical element and determine the focal length of lens L2 so that desired average focal length is achieved in output laser beam — J

determine construction of DOE D2 to produce desired focal length through lens L2 — K

FIG 3C3

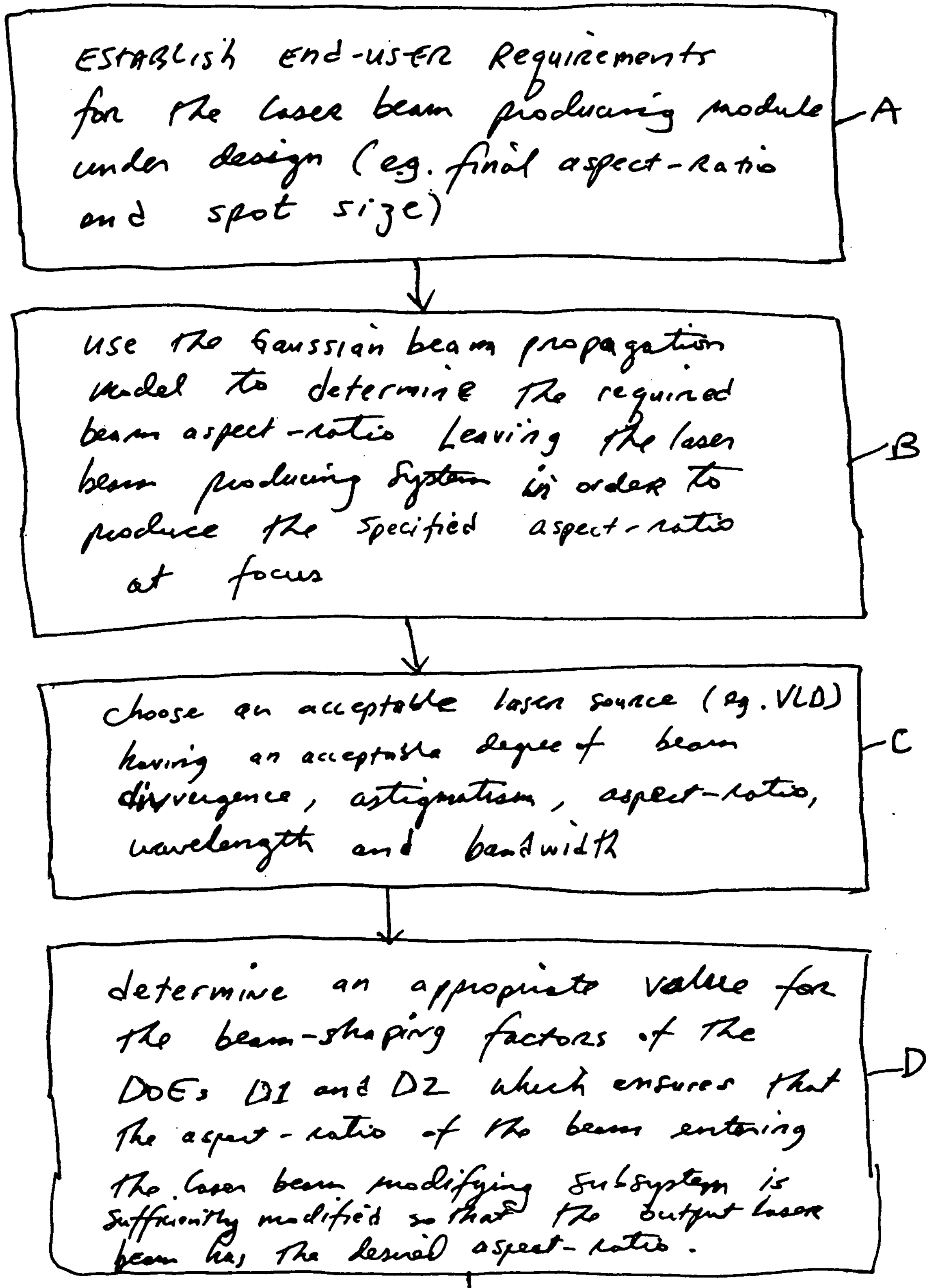

ESTABLISH END-USER Requirements for the laser beam producing module under design (eg. final aspect-ratio and spot size)
A
use the Gaussian beam propagation model to determine the required beam aspect-ratio leaving the laser beam producing system in order to produce the specified aspect-ratio at focus
B
choose an acceptable laser source (eg. VLD) having an acceptable degree of beam divergence, astigmatism, aspect-ratio, wavelength and bandwidth
C
determine an appropriate value for the beam-shaping factors of the DOEs D1 and D2 which ensures that the aspect-ratio of the beam entering the laser beam modifying subsystem is sufficiently modified so that the output laser beam has the desired aspect-ratio.
D

FIG. 3D1 A

A

determine the construction angles Θ_{i1}, Θ_{d1}, Θ_{i2}, Θ_{d2}, β) expressed at reconstruction wavelength λ_R) for the two DOEs D1 and D2 which provides an optical subsystem wherein the laser beam output from the second DOE D2 thereof has (1) effectively zero net beam dispersion, and (2) the desired aspect-ratio determined at Block B — E

determine the convergence of the beam leaving lens L1 that will adjust or eliminate the astigmatism produced by the VLD — F

Use the Gaussian beam propagation model to determine the required beam spot size leaving the laser beam producing system in order to produce the focused spot size determined at BLOCK A — G

determine the distance from the VLD to the first lens element L1 that produces an output laser beam having the desired beam size determined at Block G — H

B

(B)

determine the focal length of lens element L1 that produces a beam with the convergence determined in block F

I

FIG 3D3

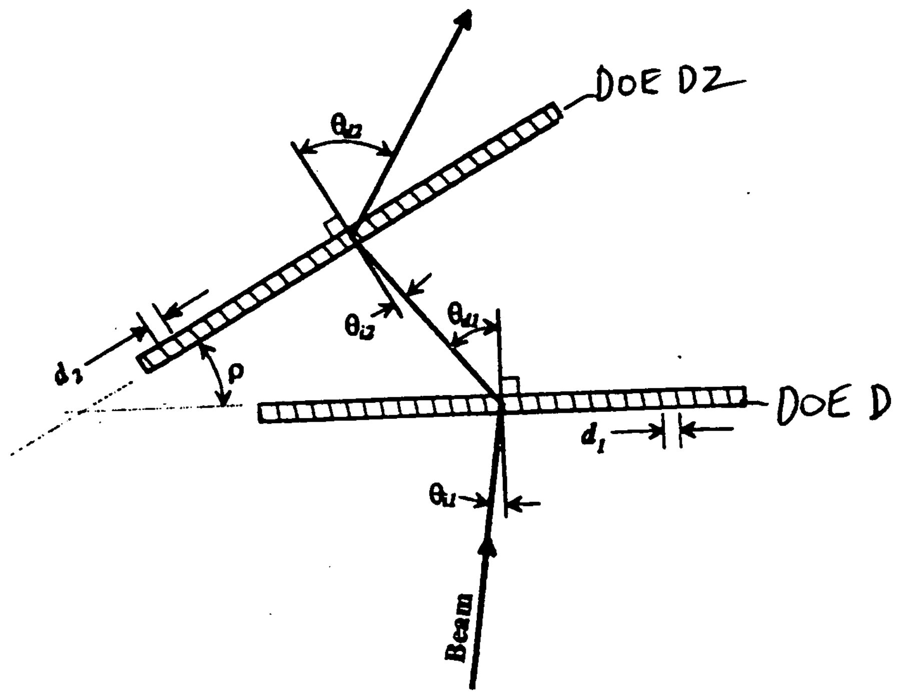


FIG. 3E

Choose values for compression/expansion ratios M_1 and M_2 so that the beam shaping factor satisfies $M = M_1 M_2$; choose reconstruction (design) wavelength λ_R, and angle of incidence θ_{i1}. — A

↓

Solve for the angle of diffraction θ_{d1} at DOE D1 using Equation No. 4 — B

↓

Solve for the fringe structure spacing d_1 of DOE D1 using Equation No. (1) — C

↓

Solve for the angle of incidence θ_{i2} at DOE D2, using Equation No. (7) — D

↓

Solve for the DOE tilt angle, ρ, using Equation No. (3) — E

↓

(A)

FIG 3F1

A

Solve for the angle of diffraction θ_{d2} at DOE D2 using equation No. (5). — F

Solve for the fringe spacing d_2 within DOE D2 using equation No (2) — G

FIG. 3F2

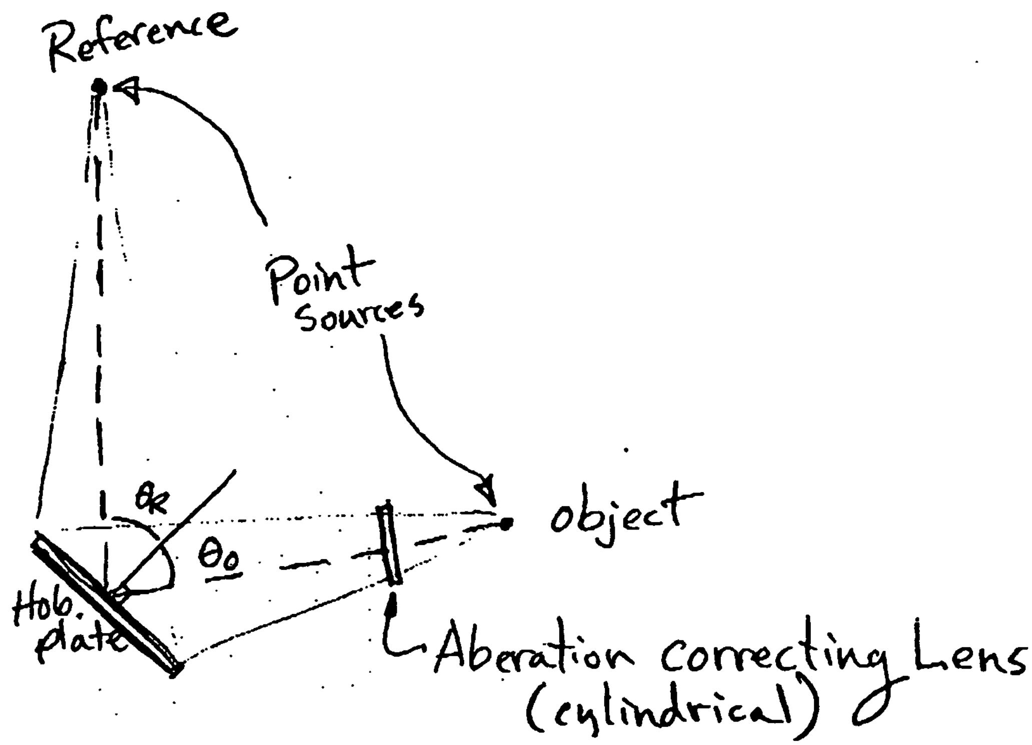
A

Convert the design parameters $\theta_{i1}, \theta_{d1}, \theta_{i2}, \theta_{d2}$, (and f_2) expressed at the reconstruction wavelength λ_R into construction parameters expressed at the construction wavelength λ_c, namely: θ_{O1}, θ_{R1} for HOE H1; and θ_{O2}, θ_{R2} for HOE H2

B

In the case of variable spatial frequency DOES, use computer-ray tracing to determine the distances of the object and reference (beam) sources relative to the holographic recording medium (as well as the distances of any aberration-correcting lenses therefrom) employed during the holographic recording process

FIG 4A



θ_o = OBJECT BEAM ANGLE OF INCIDENCE

θ_r = REFERENCE BEAM ANGLE OF INCIDENCE

FIG. 4B

formulate within a digital computer system, a mathematical description of the object and reference beam wavefronts used to construct DOE D1 and DOE D2, during optical formation thereof when using the Holographic Recording method shown in Fig. 4B — A

↓

use the digital computer system to formulate a mathematical description of the interference pattern that is generated by mathematically adding the mathematical model of the object beam wavefront to the reference beam wavefront, to provide a spatial function of the computer generated/represented interference pattern — B

↓

use the digital computer system to sample the spatial function of the computer generated/represented interference pattern along the x and y directions thereof to produce a large set of sampled values of varying amplitude transmittance associated with the computer generated interference pattern — C

↓

A

FIG. 4C1

A

transfer the sampled light transmittance (reflection) values from the computer system to the drivers of a graphical plotting tool — D

use the set of sampled transmittance values to plot the two-dimensional sampled interference pattern on paper or other high resolution recording medium — E

photographically reduce the two-dimensional density (amplitude transmittance) plot on a light transmissive (or reflective) recording medium, to produce a master CGH for use in making CGH copies — F

use suitable copying apparatus to copy the CGH master onto a higher diffraction efficiency medium (DCG, photoresist, or suitable surface relief material) to form improved CGH copy — G

FIG. 4C2

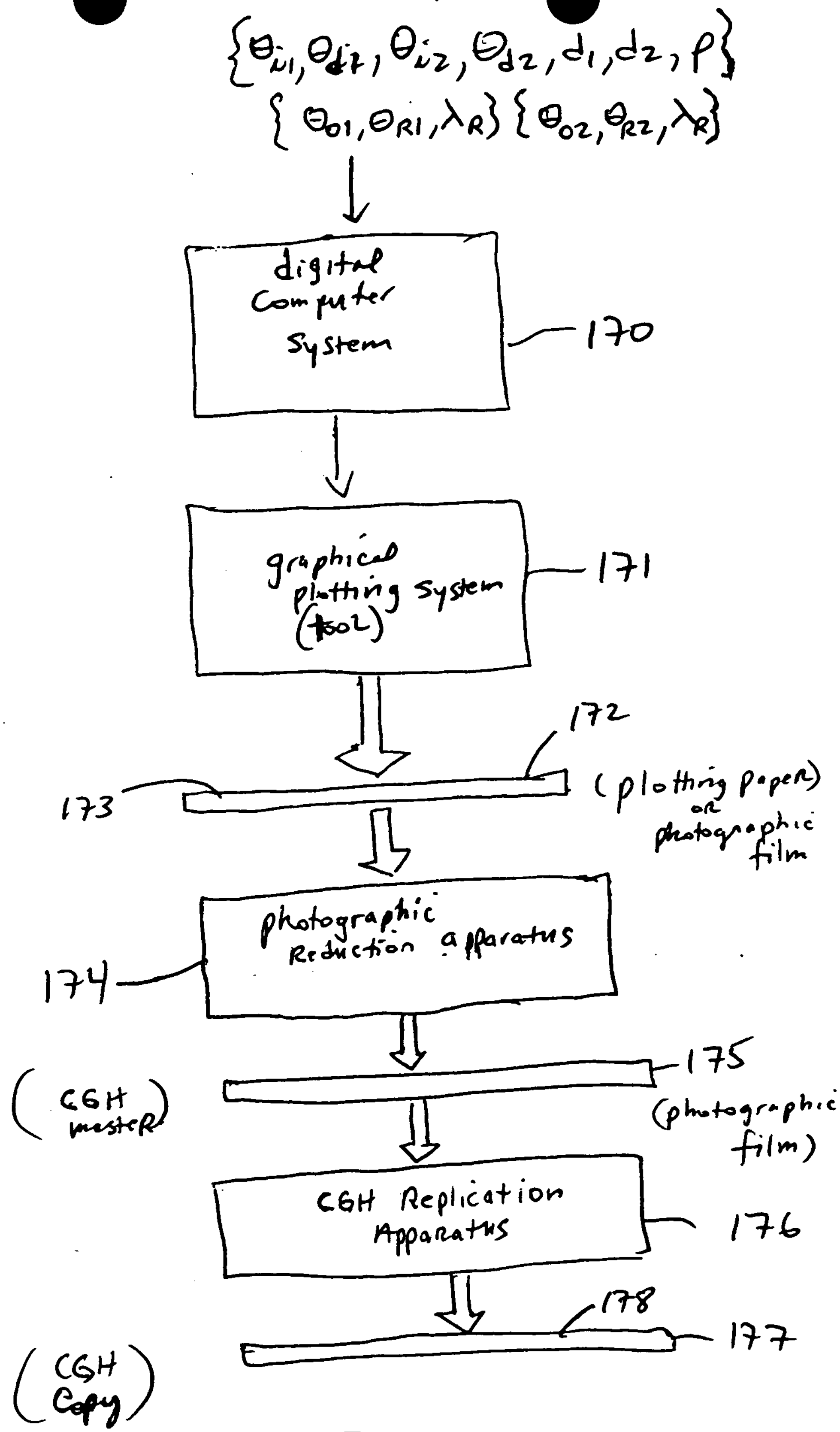

$\{\theta_{i1}, \theta_{d1}, \theta_{i2}, \theta_{d2}, d_1, d_2, \rho\}$
$\{\theta_{O1}, \theta_{R1}, \lambda_R\}$ $\{\theta_{O2}, \theta_{R2}, \lambda_R\}$
digital Computer System
170
graphical plotting system (tool)
171
172
173
(plotting paper) or photographic film
photographic Reduction apparatus
174
175
(CGH master)
(photographic film)
CGH Replication Apparatus
176
178
177
(CGH Copy)

FIG 4D

Beam Dispersion Analysis

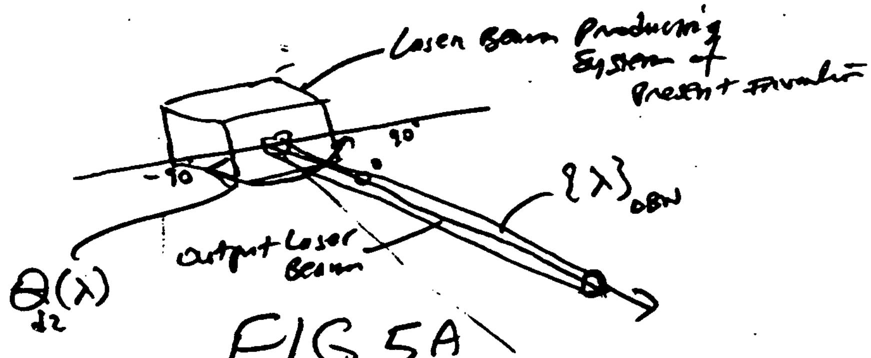


FIG. 5A

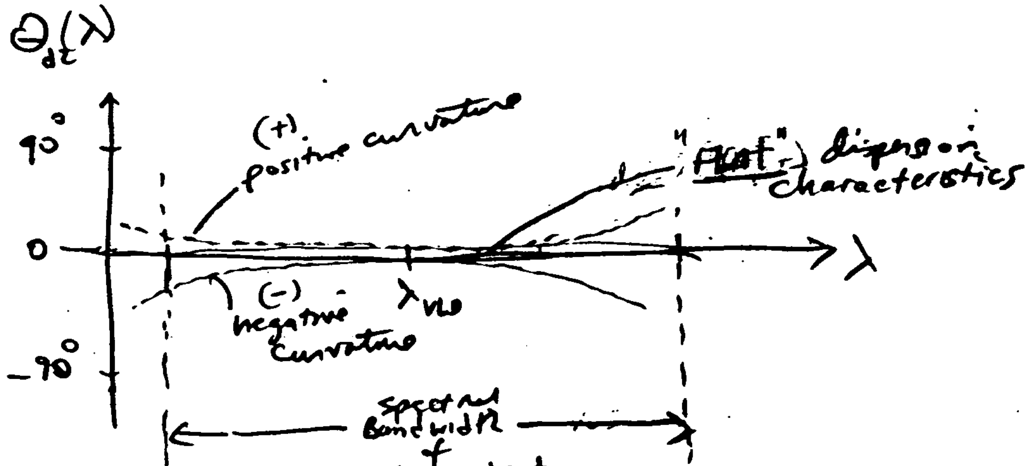


FIG. 5B

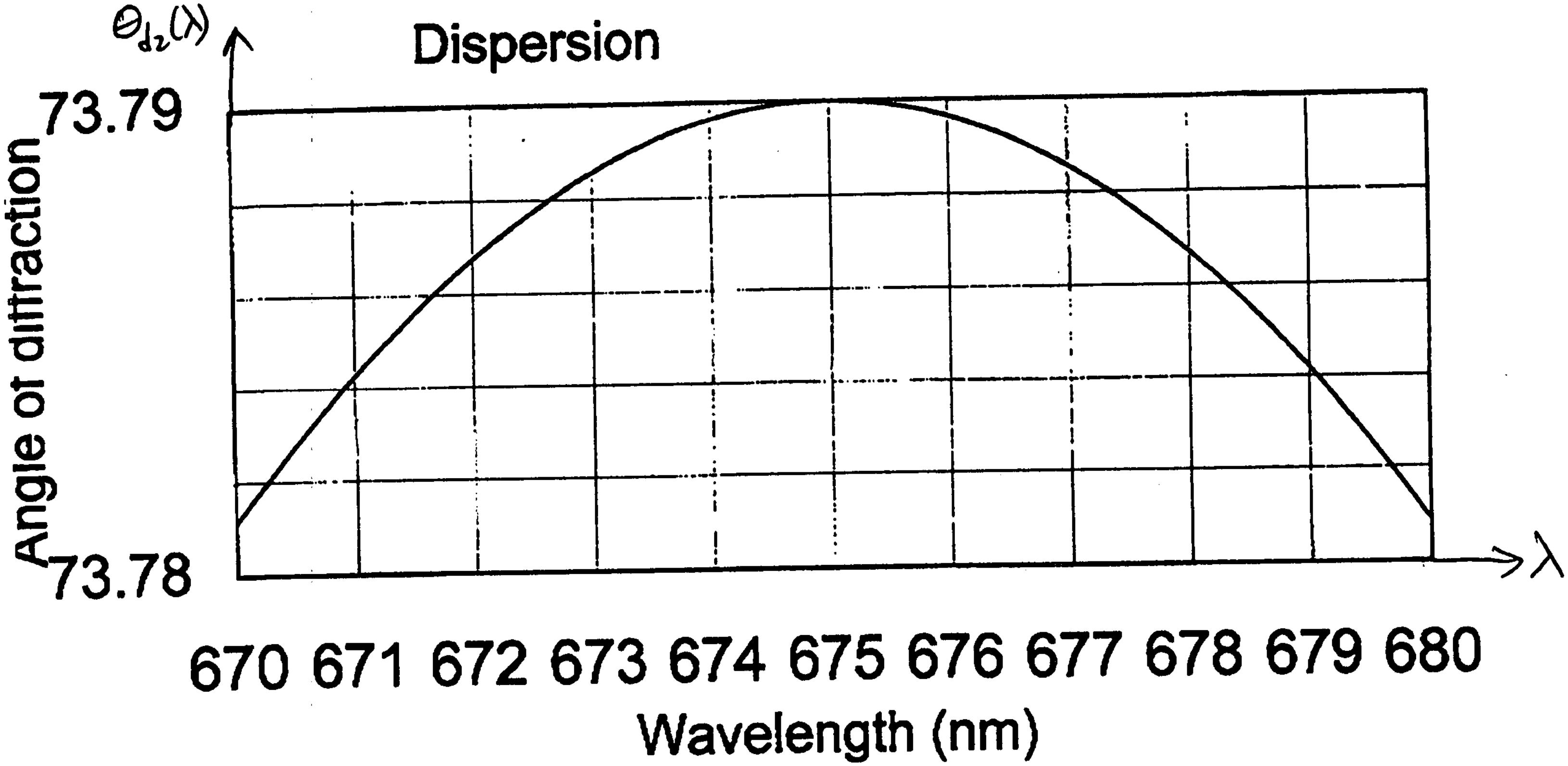

$\Theta_{d2}(\lambda)$
Dispersion
73.79
Angle of diffraction
73.78
λ
670 671 672 673 674 675 676 677 678 679 680
Wavelength (nm)

FIG 5B1

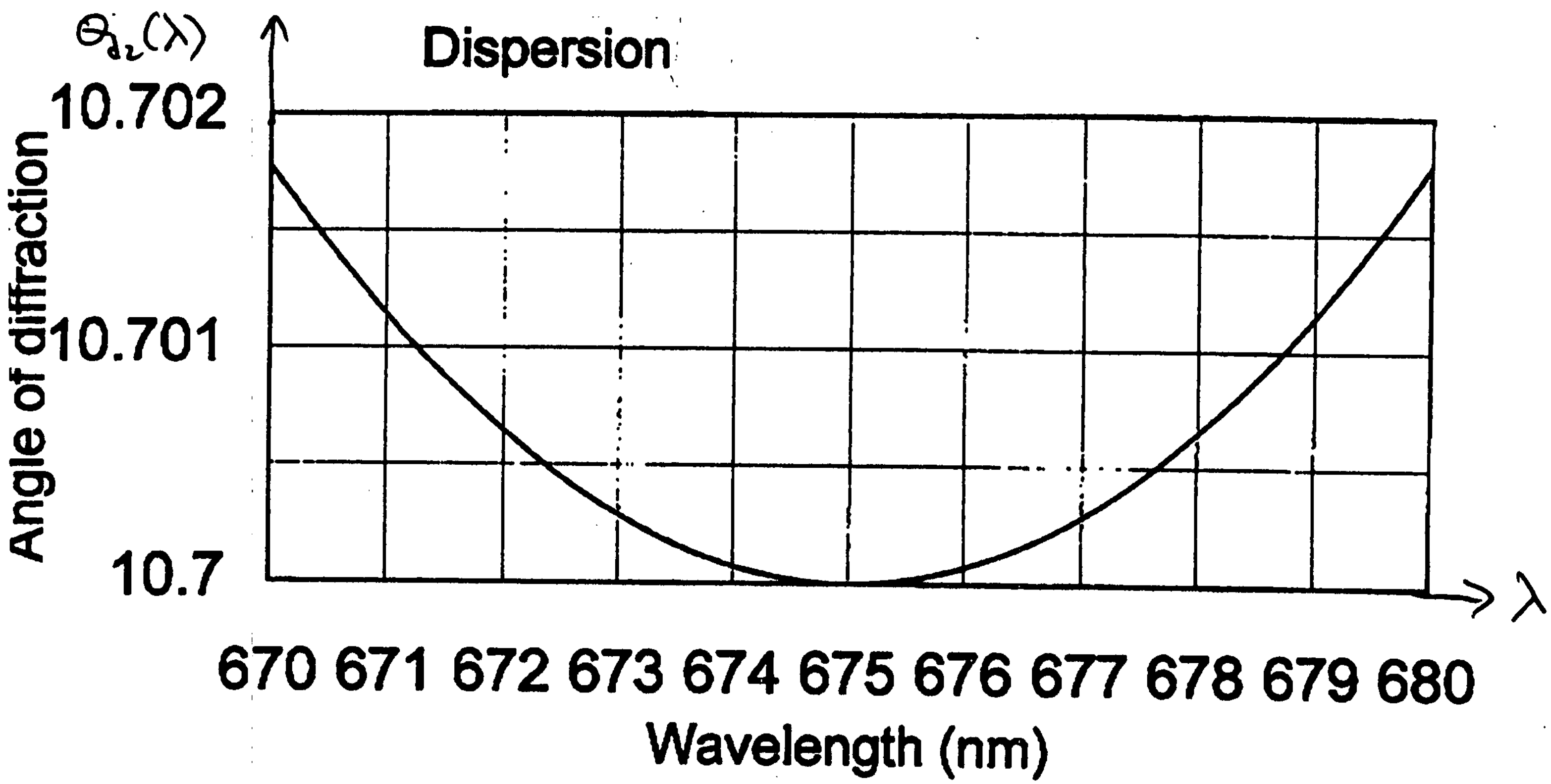

Dispersion
$\theta_{d2}(\lambda)$
Angle of diffraction
10.702
10.701
10.7
λ
670 671 672 673 674 675 676 677 678 679 680
Wavelength (nm)

FIG. 5B2

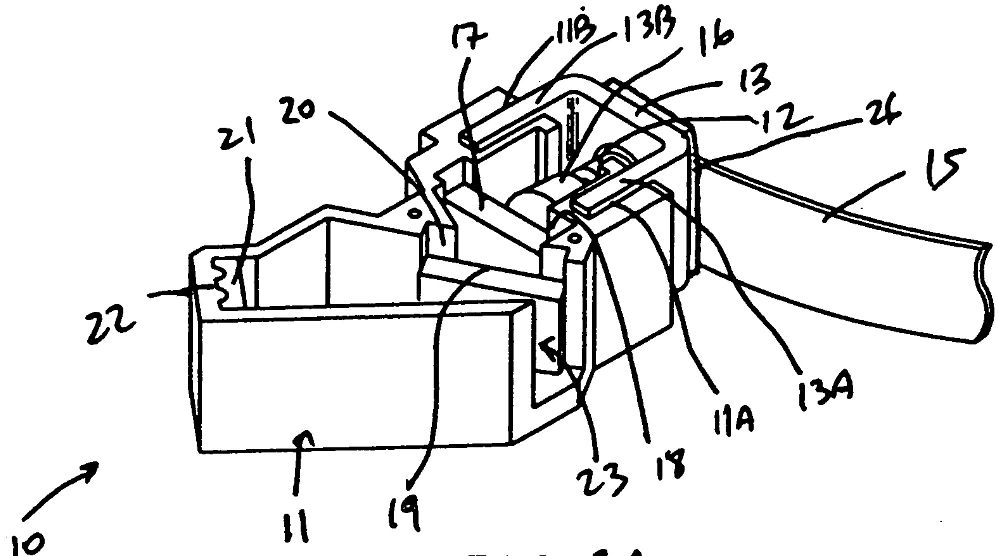


FIG. 6A

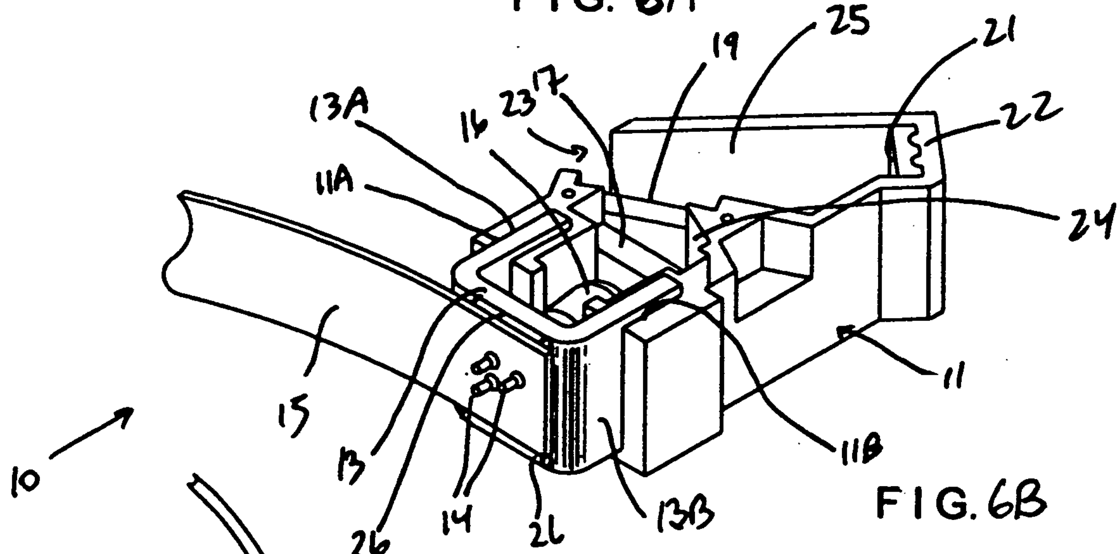


FIG. 6B

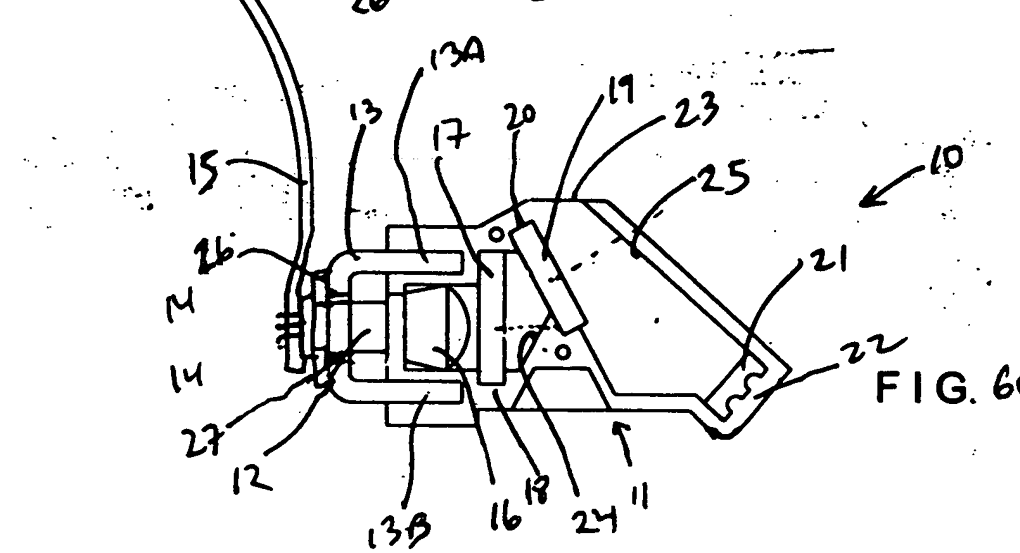


FIG. 6C

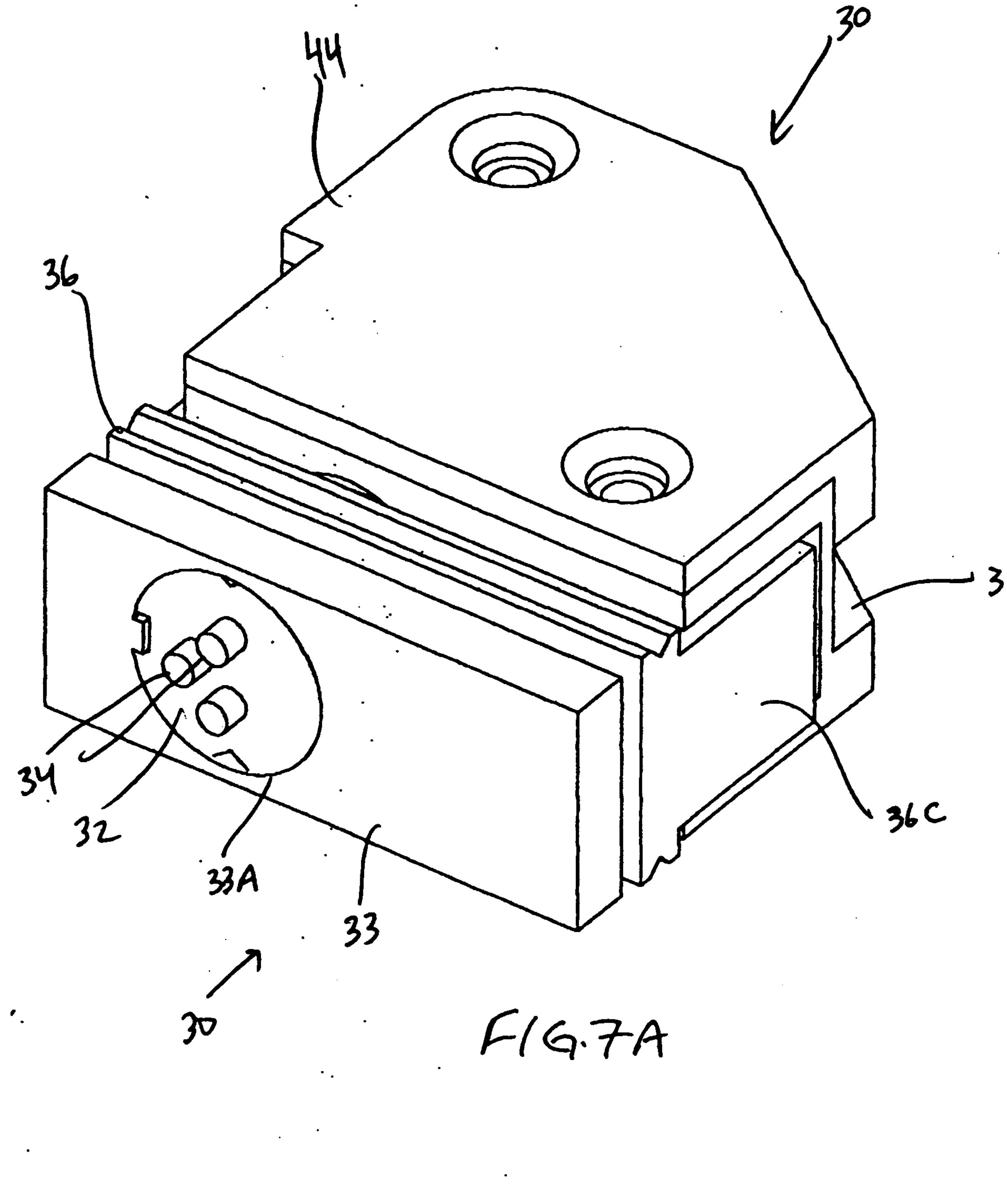


FIG. 7A

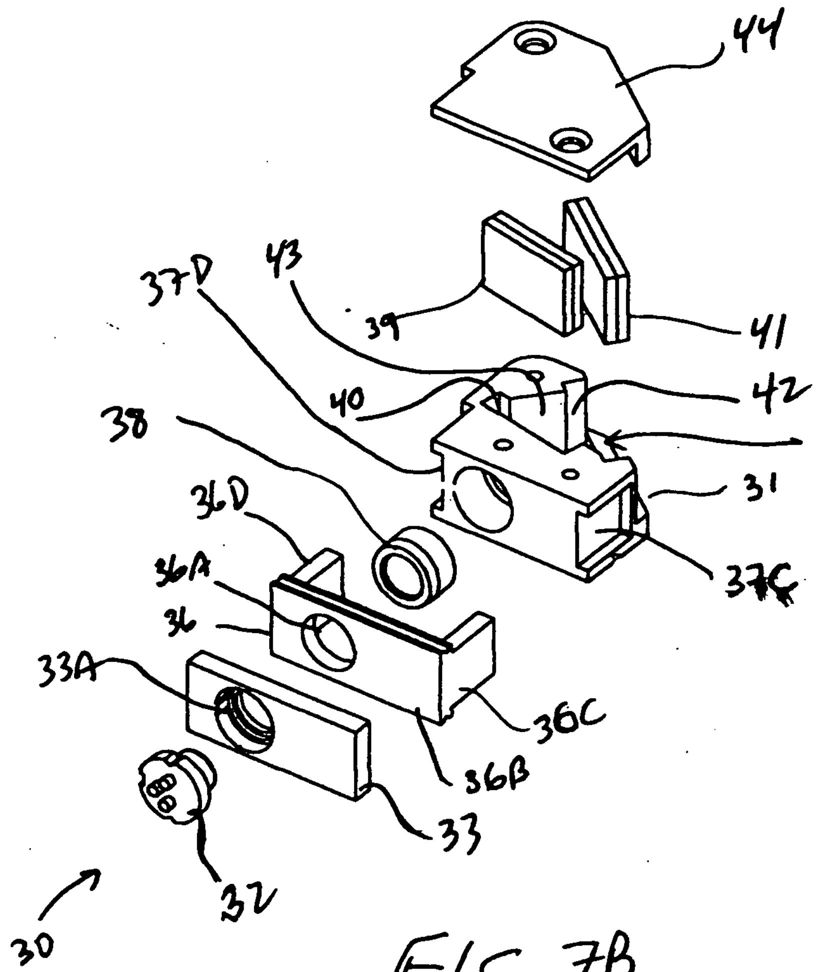


FIG. 7B

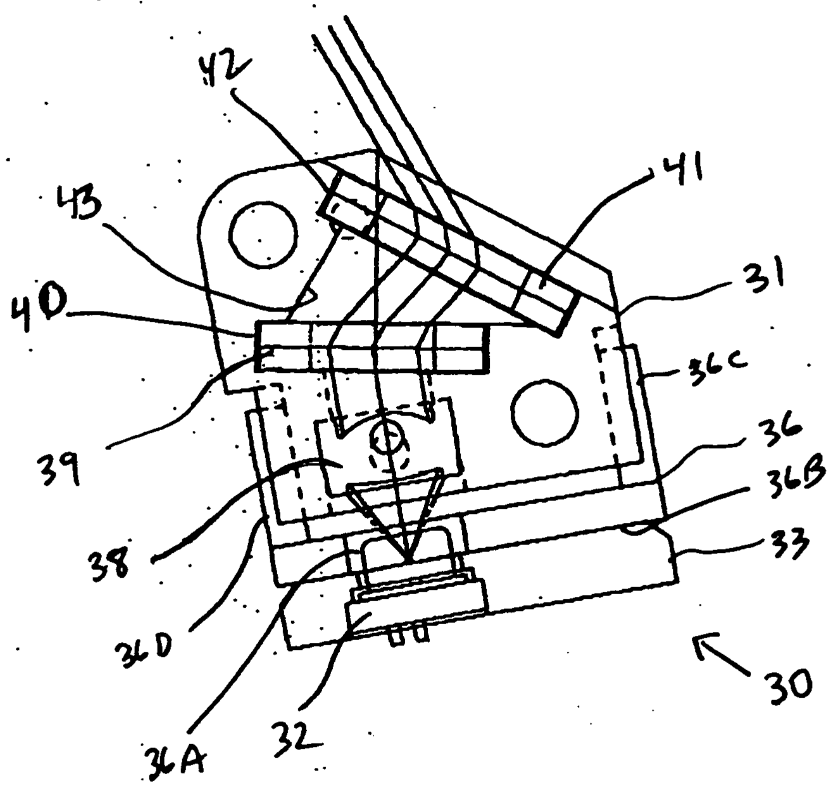


FIG. 7C

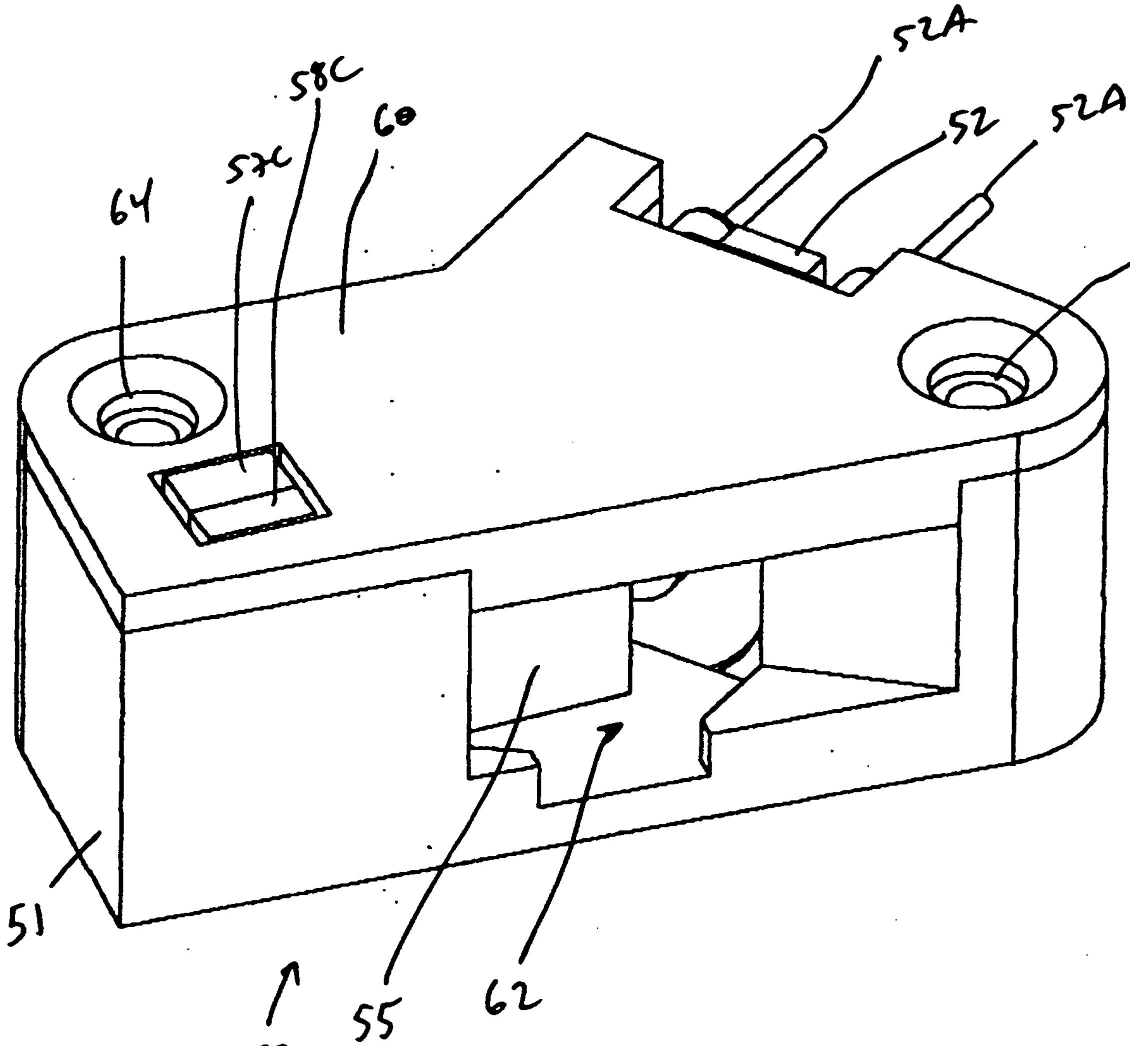


FIG. 8A

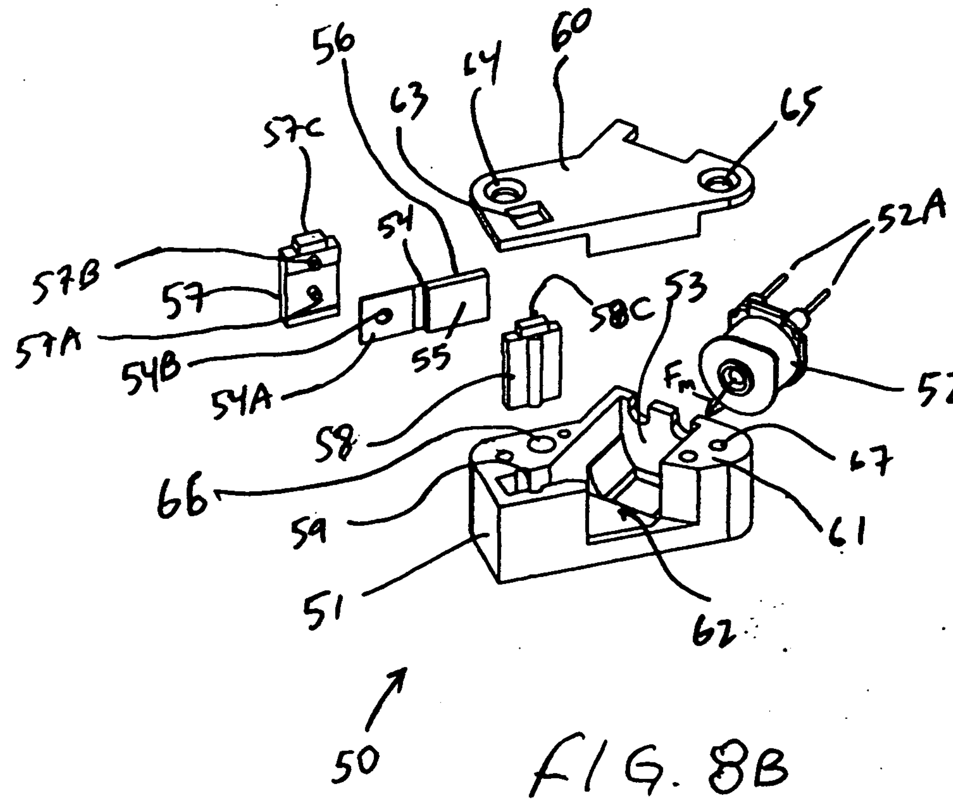

56
64
60
63
65
57C
54
52A
57B
57
58C
53
57A
54B
55
Fm
52
54A
58
67
66
59
61
51
62
50

FIG. 8B

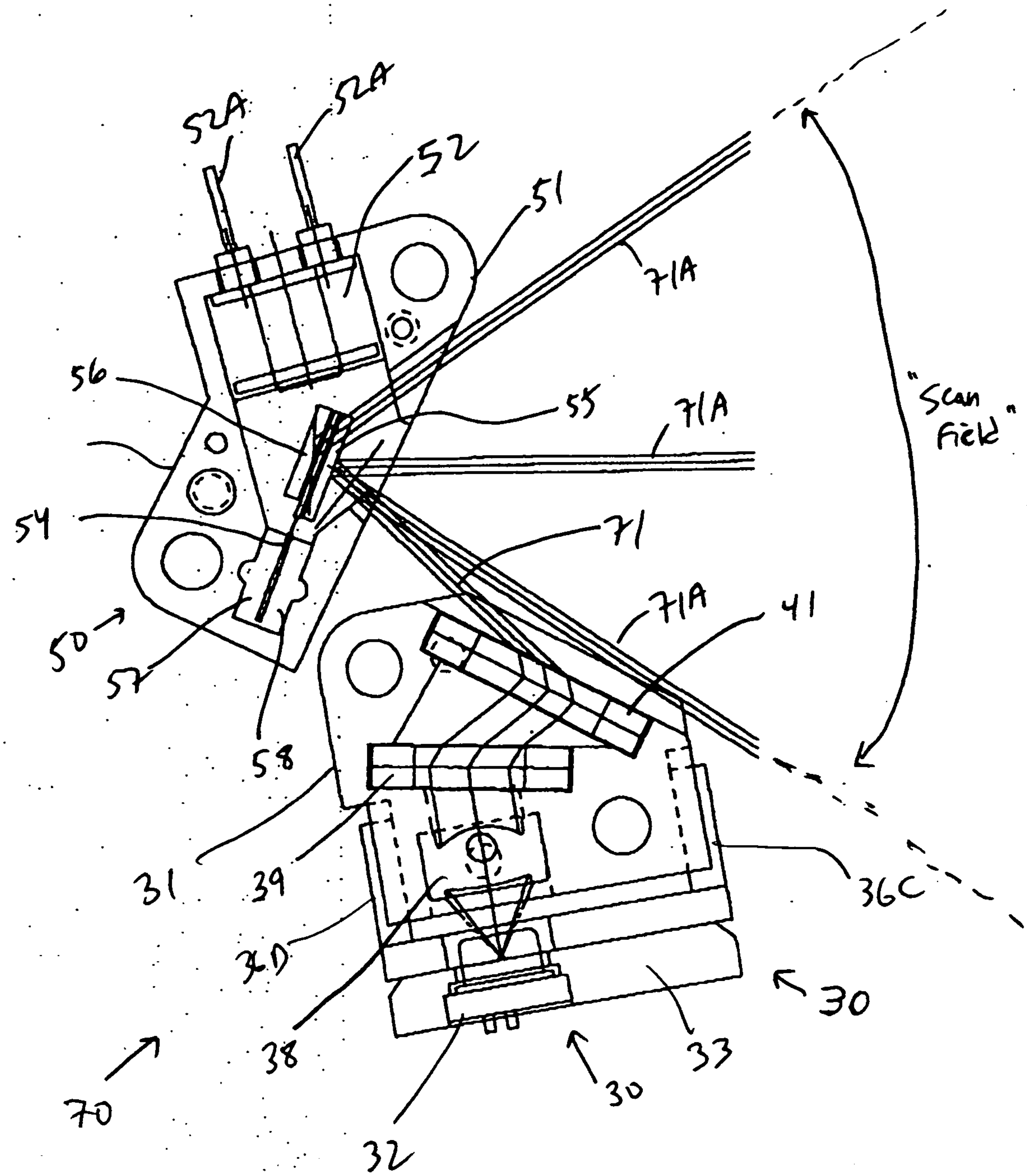

52A
52A
52
51
71A
56
55
71A
"Scan Field"
54
71
71A
41
50
57
58
31
39
36C
36D
38
30
70
33
30
32

FIG. 9

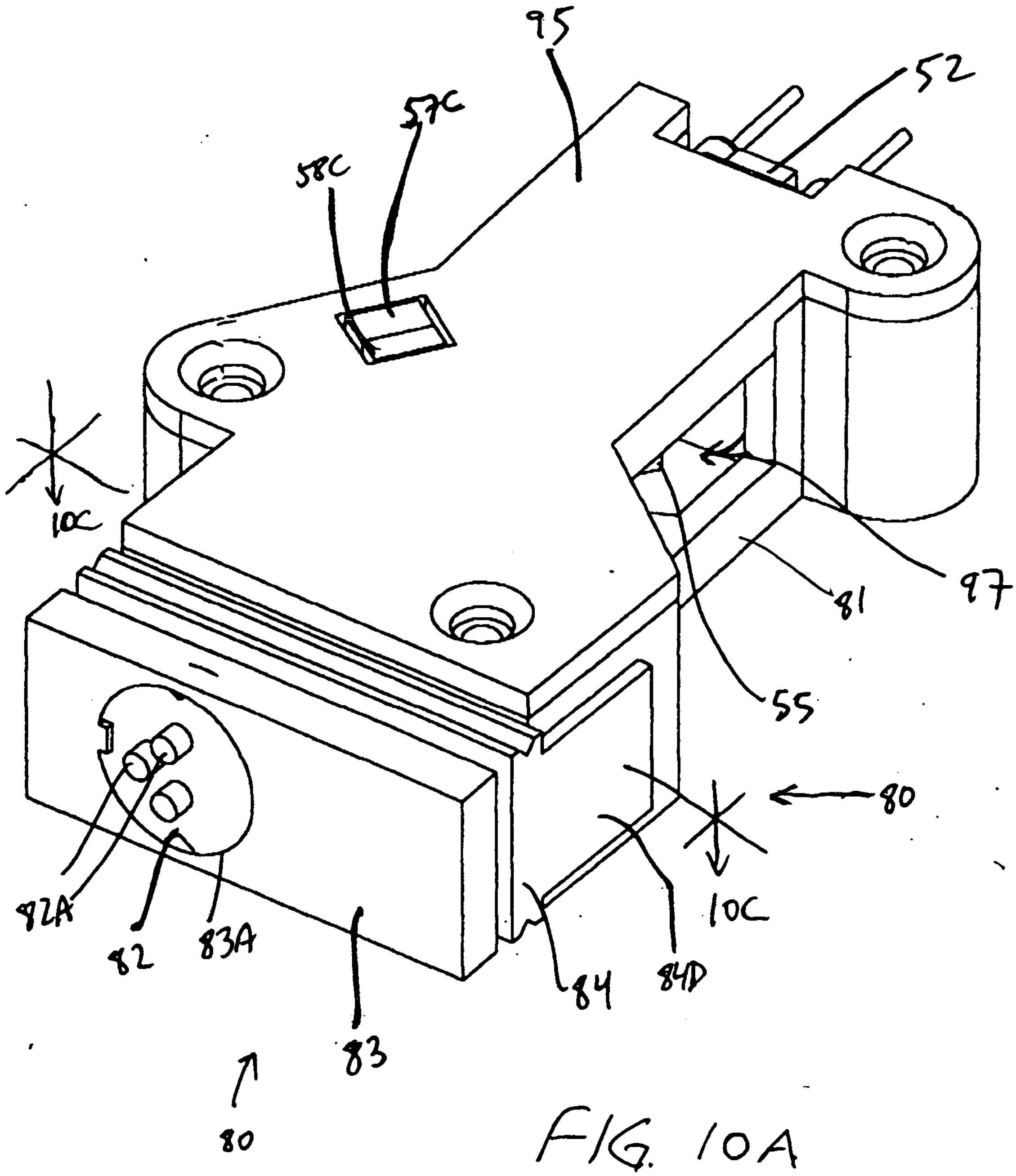


FIG. 10A

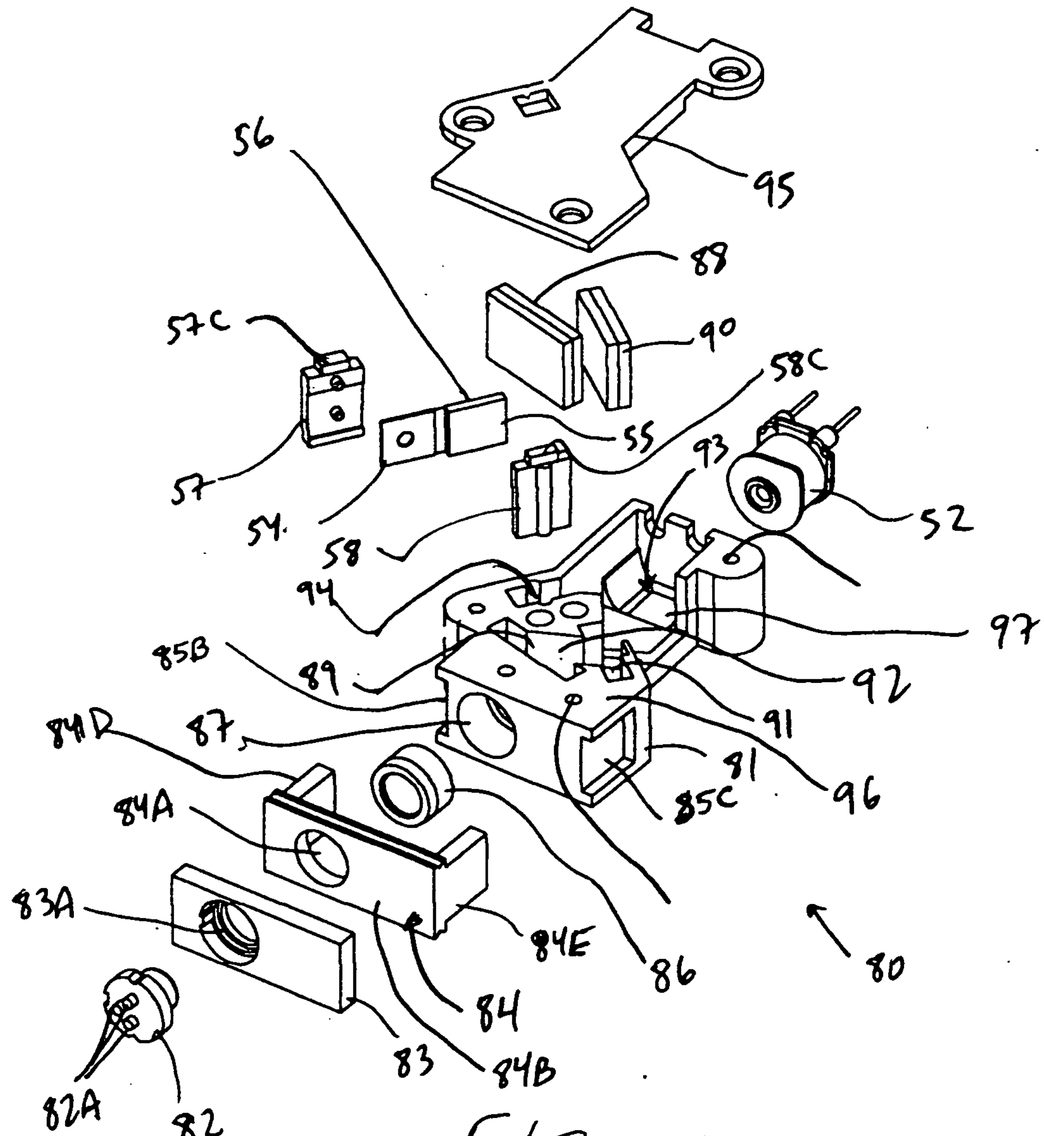

56
95
88
57C
90
58C
57
55
54
93
52
58
94
97
85B
89
92
84D
87
91
81
96
85C
84A
83A
84E
86
80
84
82A
83
84B
82

FIG 10B

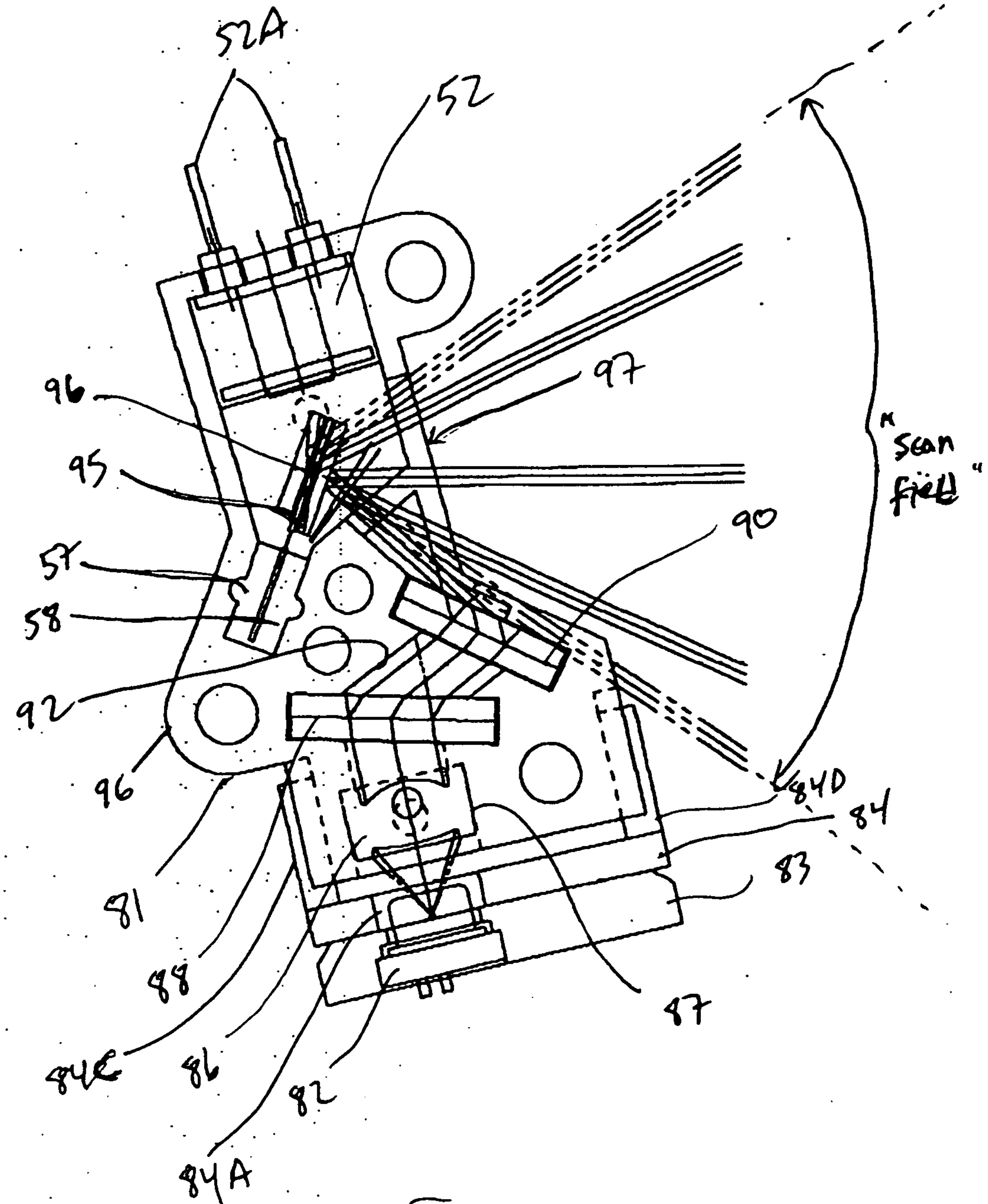
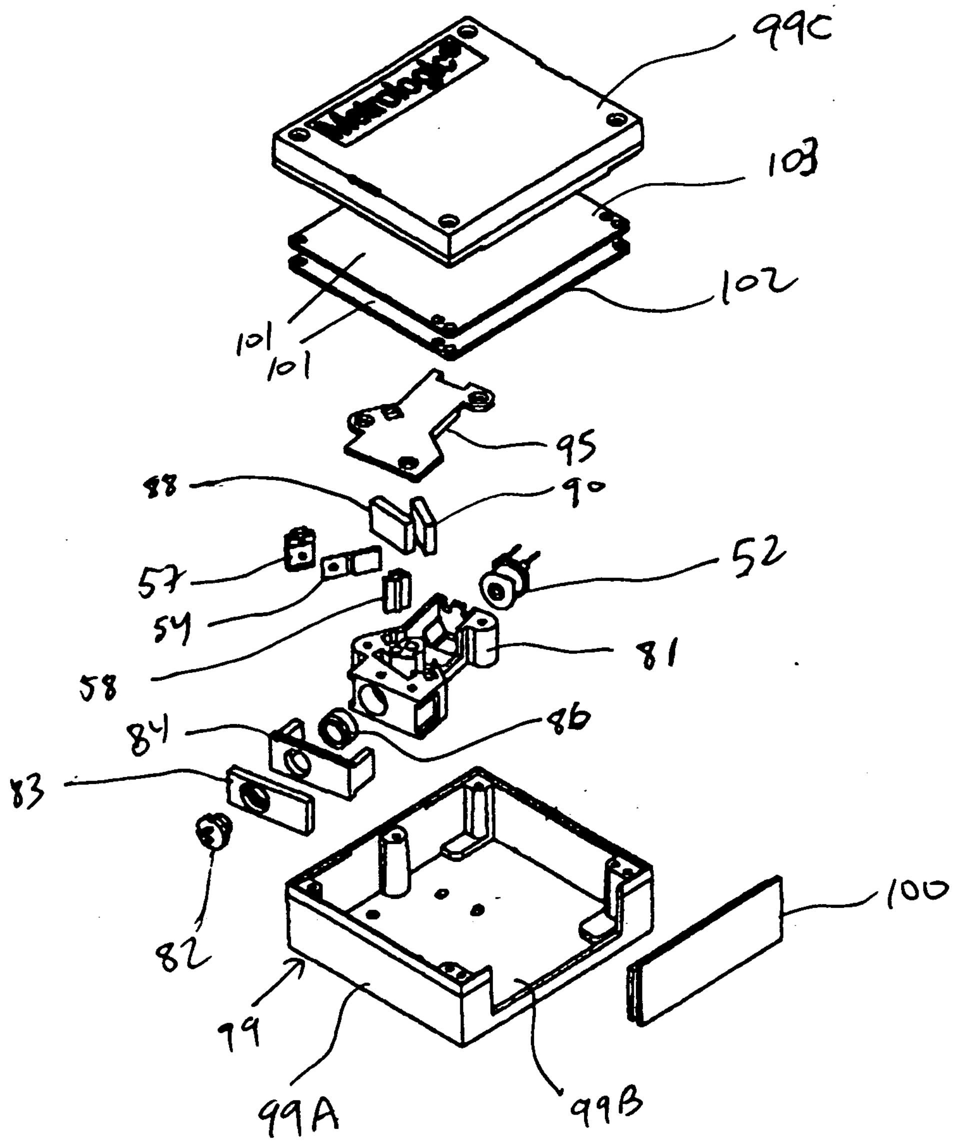

52A
52
97
96
95
"scan field"
90
57
58
92
96
84D
84
81
83
88
84C
86
87
82
84A

FIG. 10C



99C
103
102
101
101
95
88
90
57
54
52
58
81
84
86
83
82
100
99
99A
99B

FIG. 10D

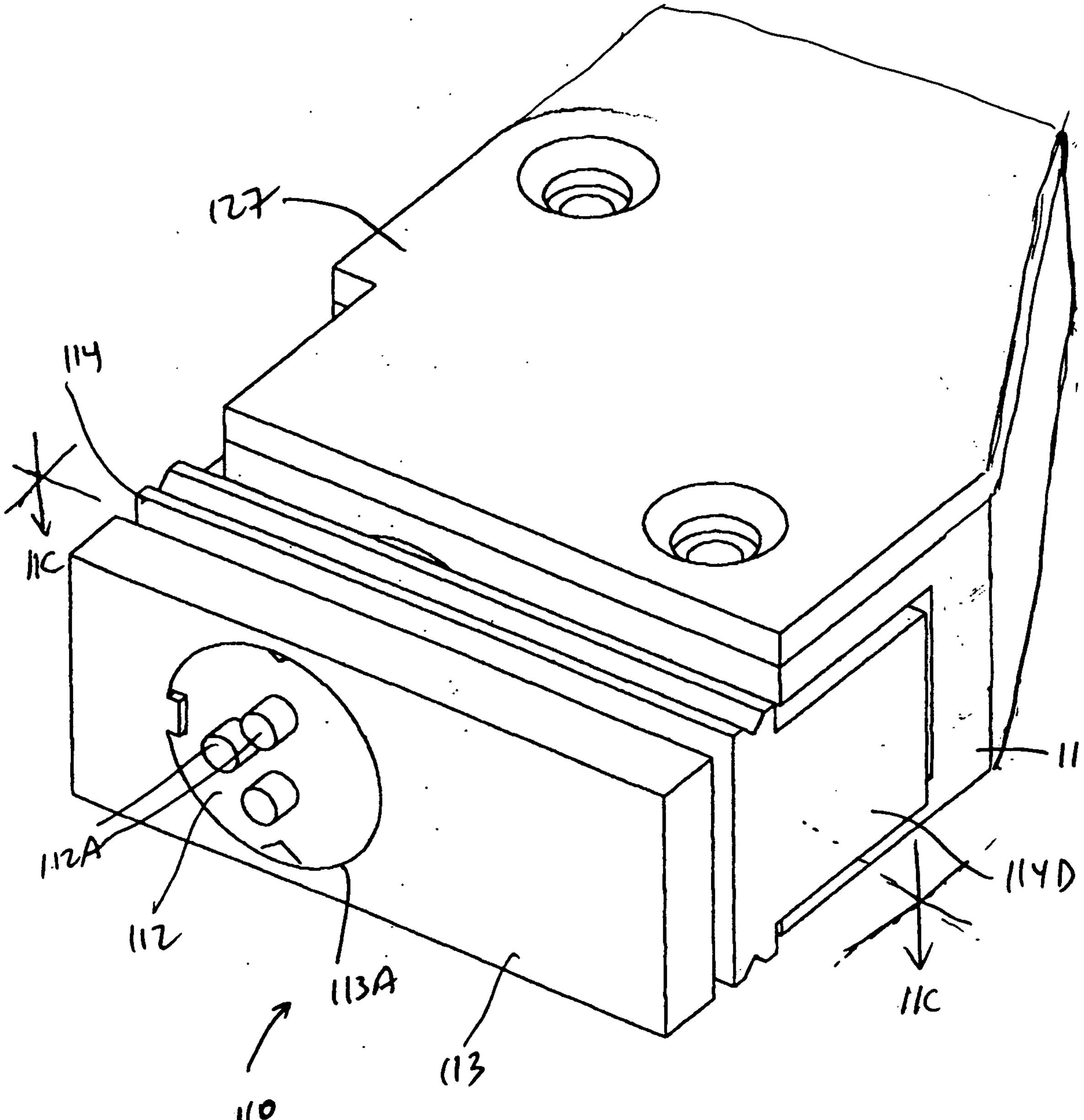


FIG. 11A

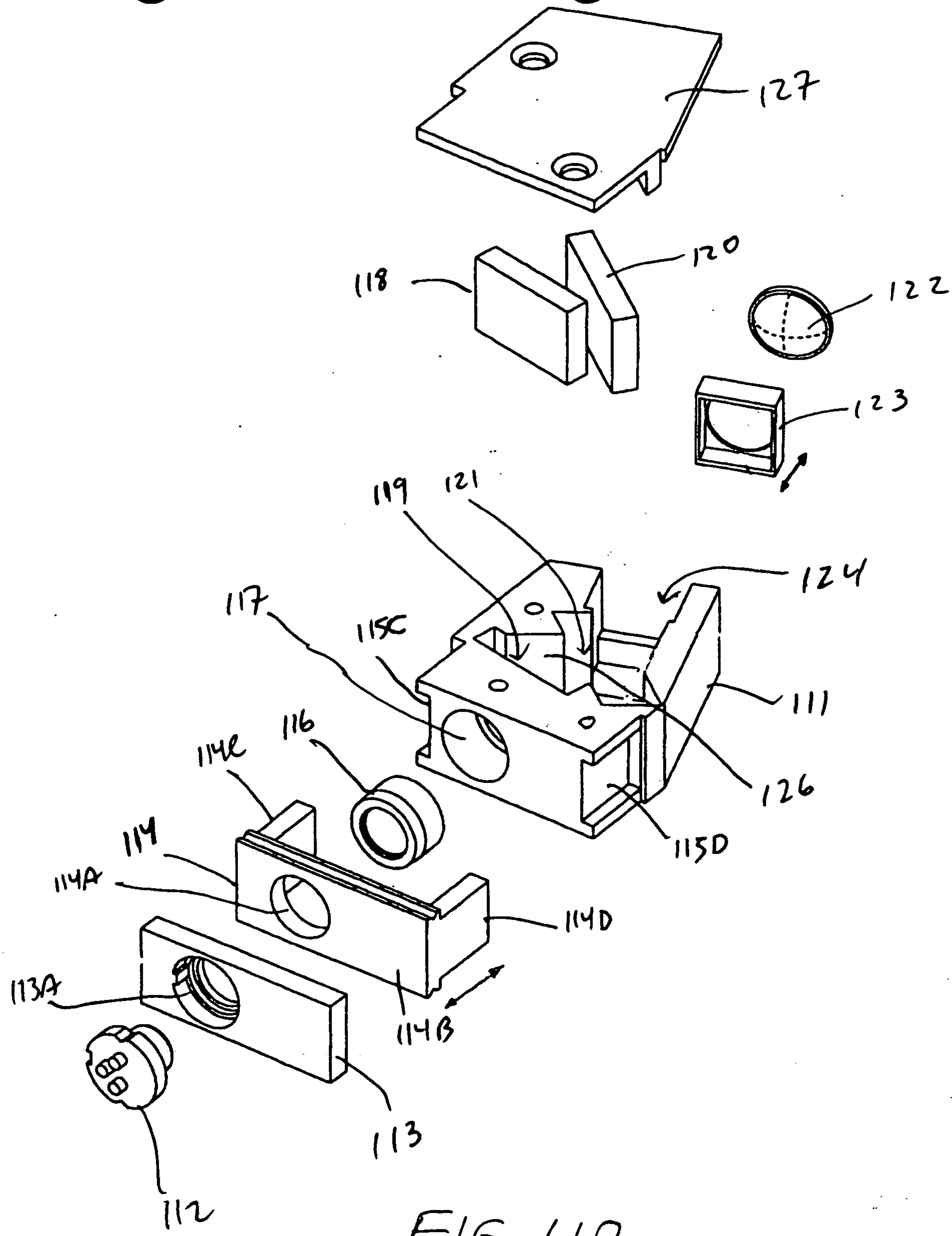

127
118
120
122
123
119
121
124
117
115C
111
126
115D
114C
116
114
114A
114D
113A
114B
113
112

FIG. 11B

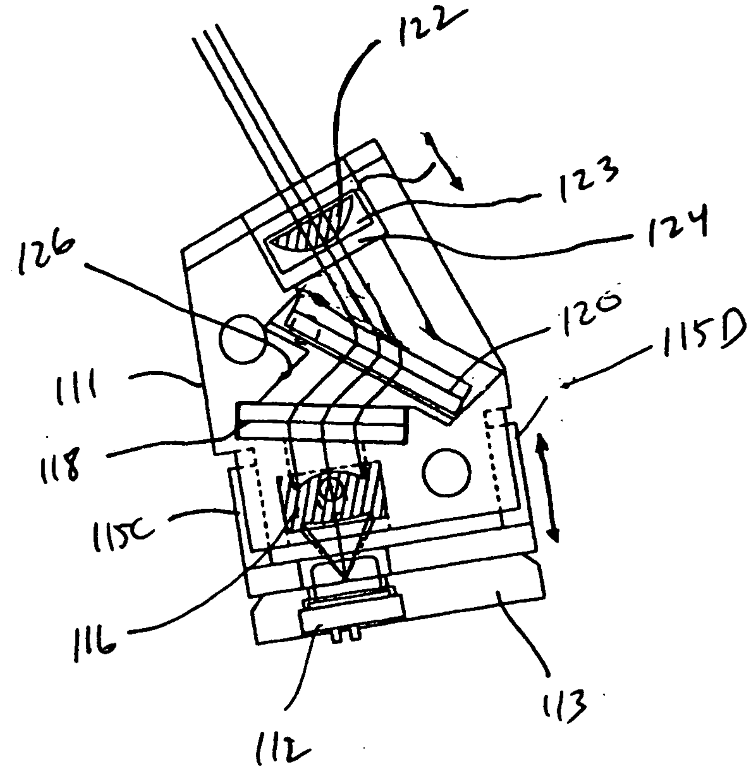


FIG. 11C

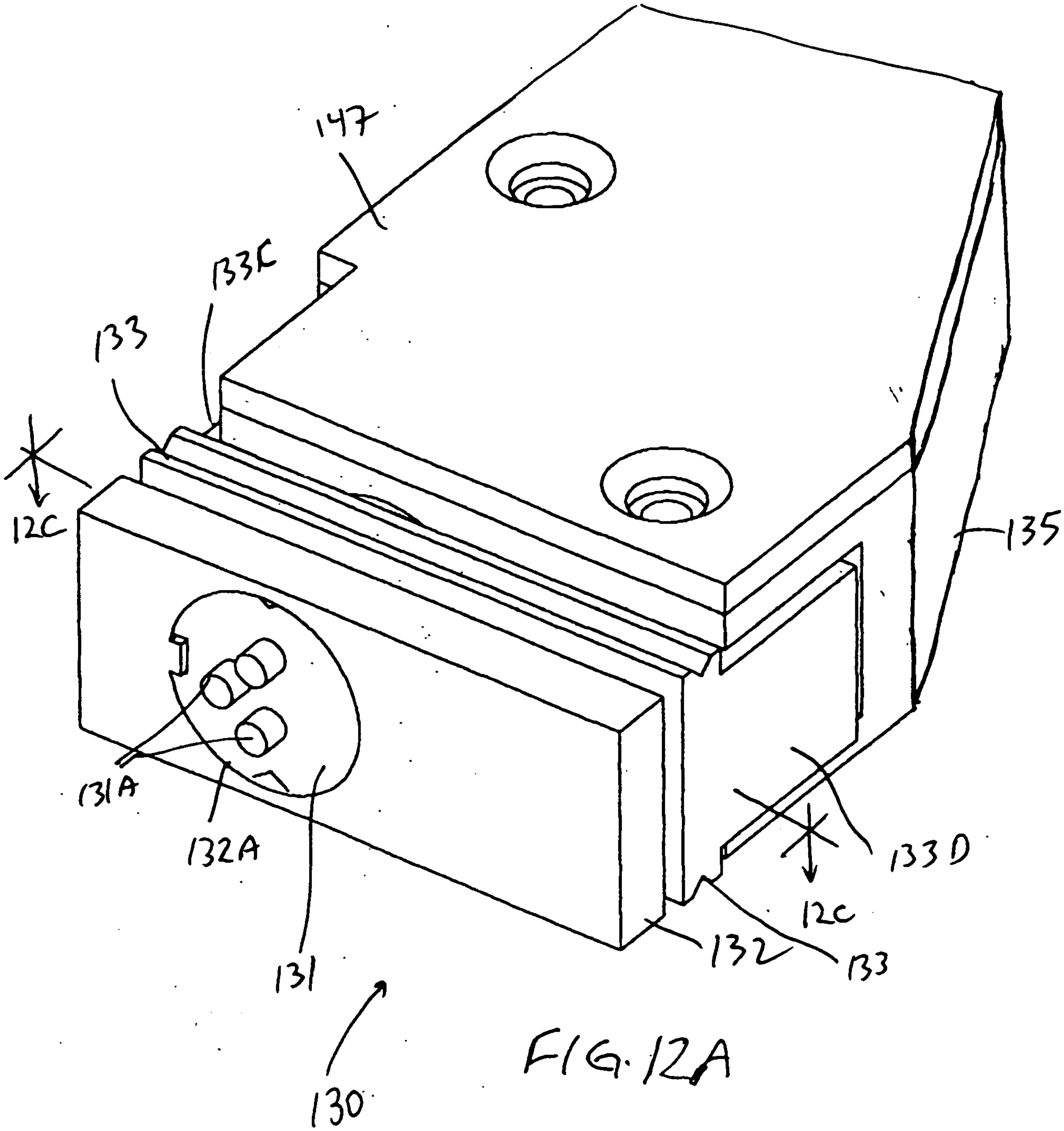


FIG. 12A

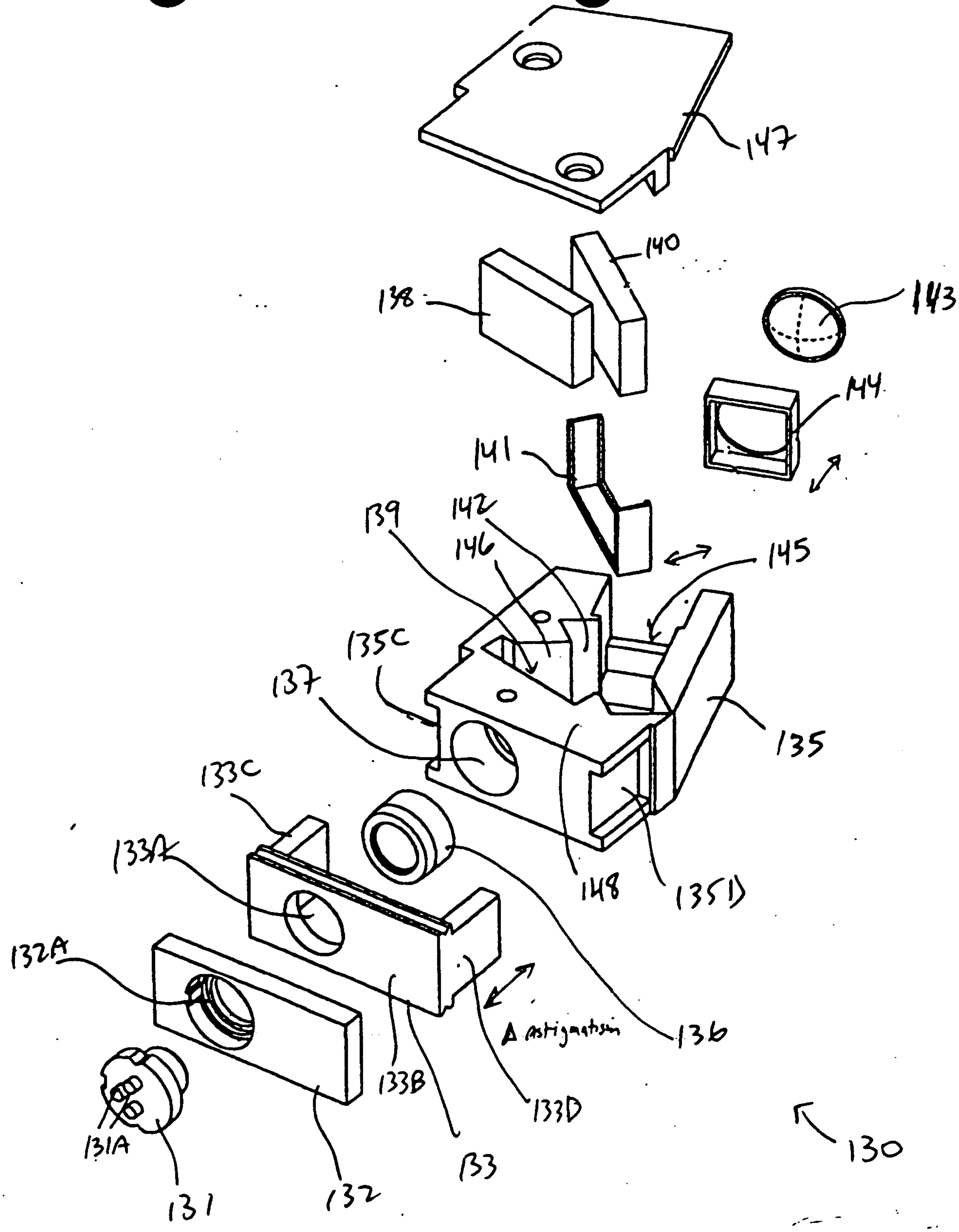

147
140
138
143
144
141
142
139
146
145
135C
137
135
133C
148
135D
133A
132A
136
A astigmatism
133B
133D
131A
131
132
133
130

FIG.12B

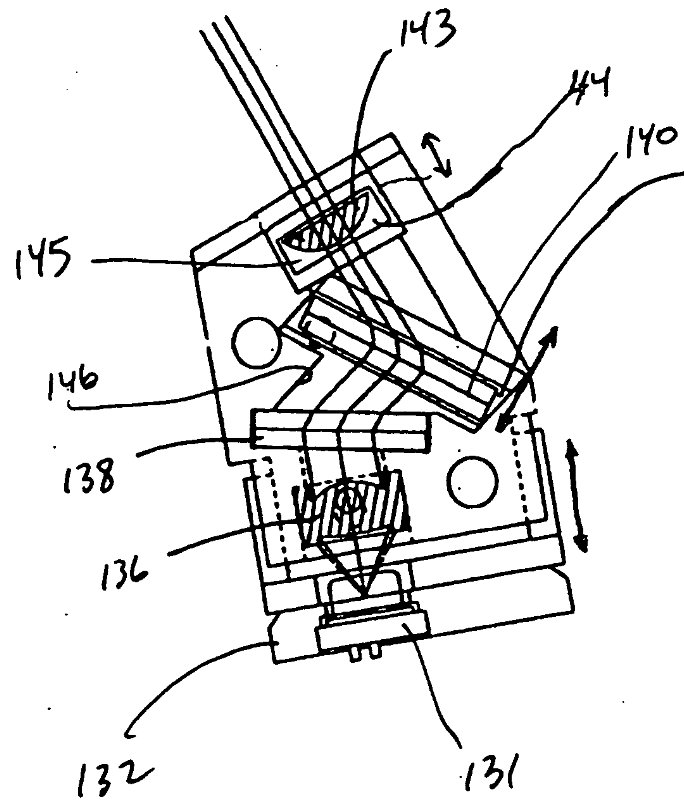


FIG. 12C

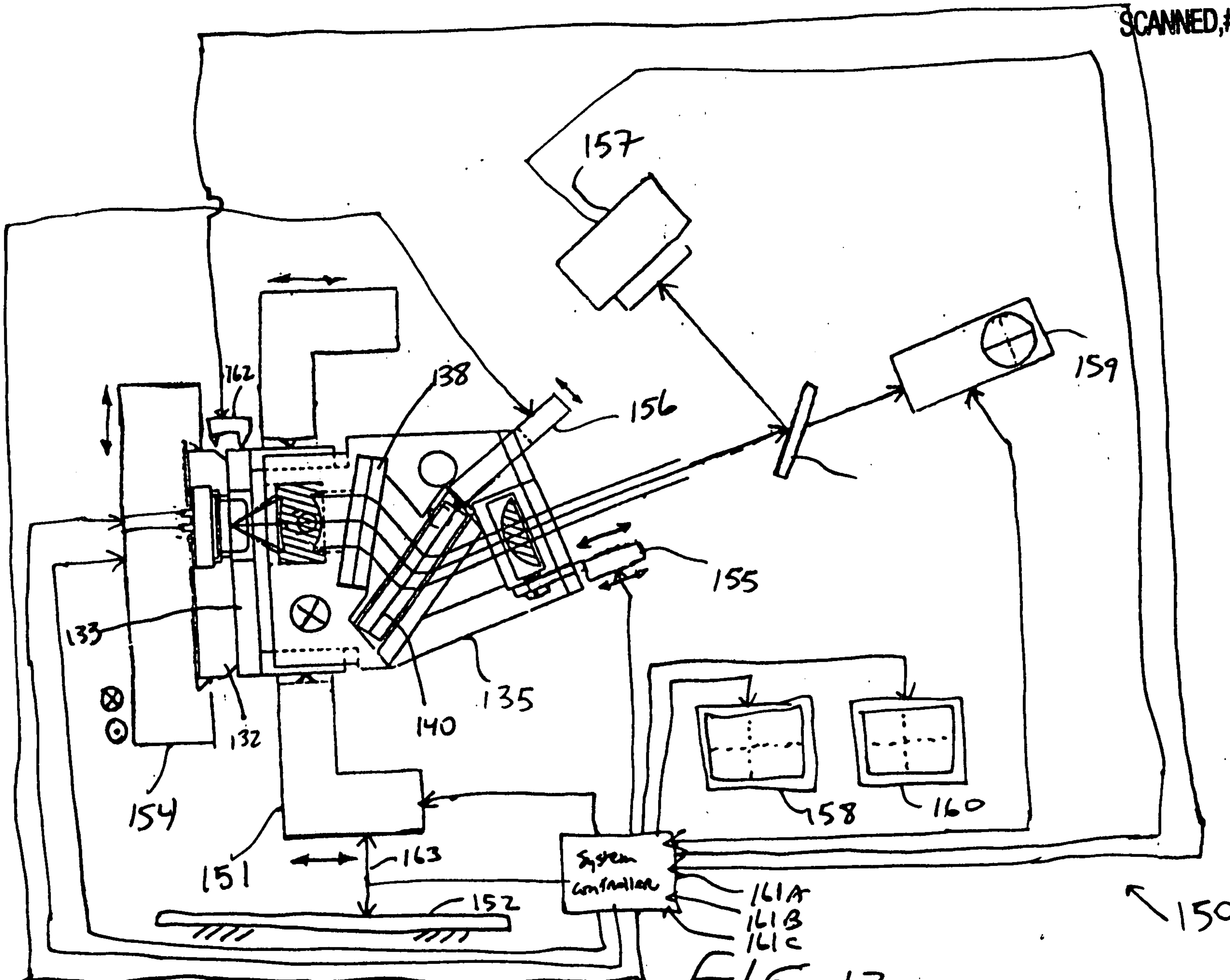

157
159
162
138
156
155
133
132
140
135
154
151
163
152
System Controller
161A
161B
161C
158
160
150

FIG. 13

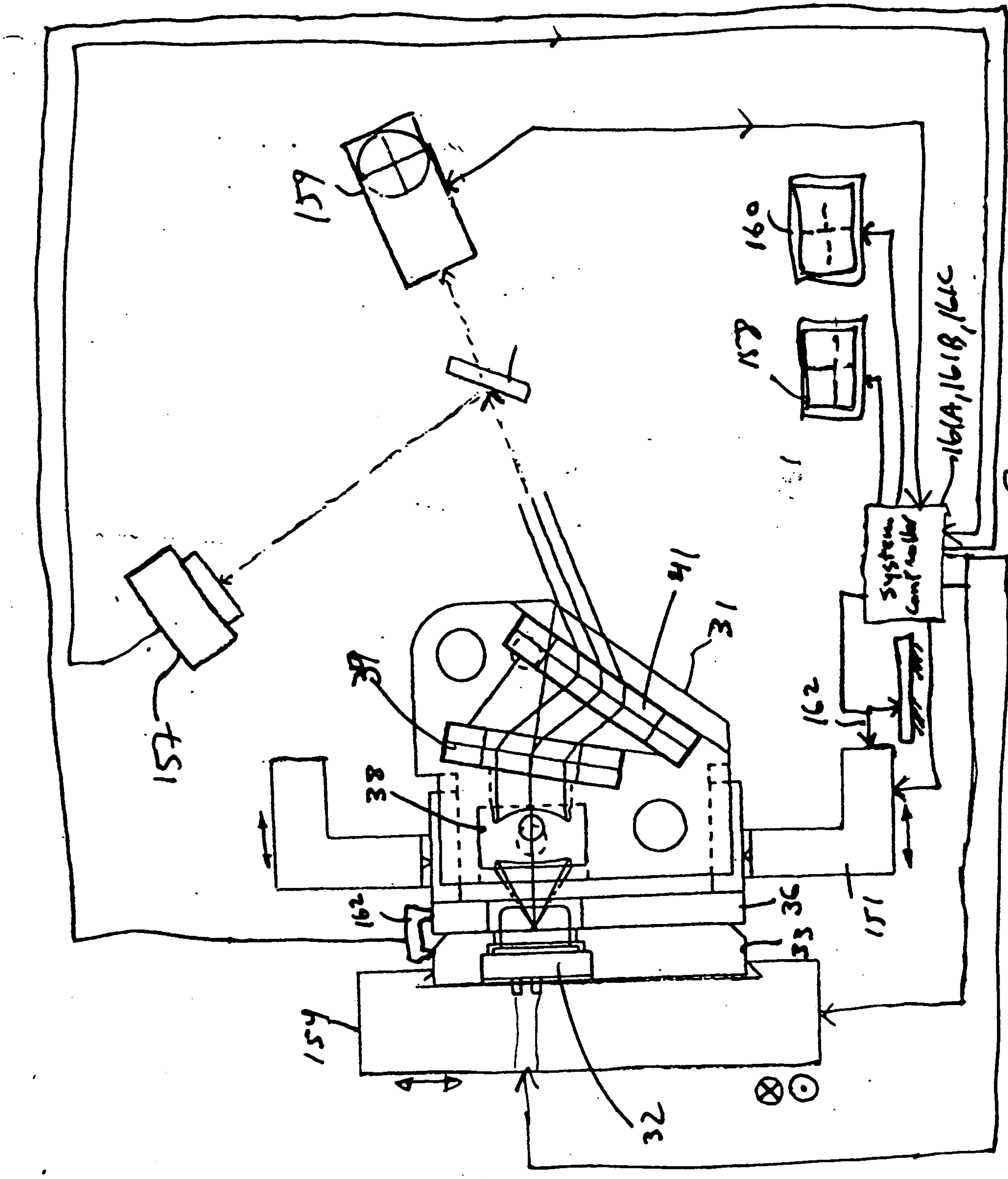

159
160
158
161A,161B,161C
System controller
157
39
38
41
31
162
162
36
33
151
154
32

FIG. 14

(Case A)

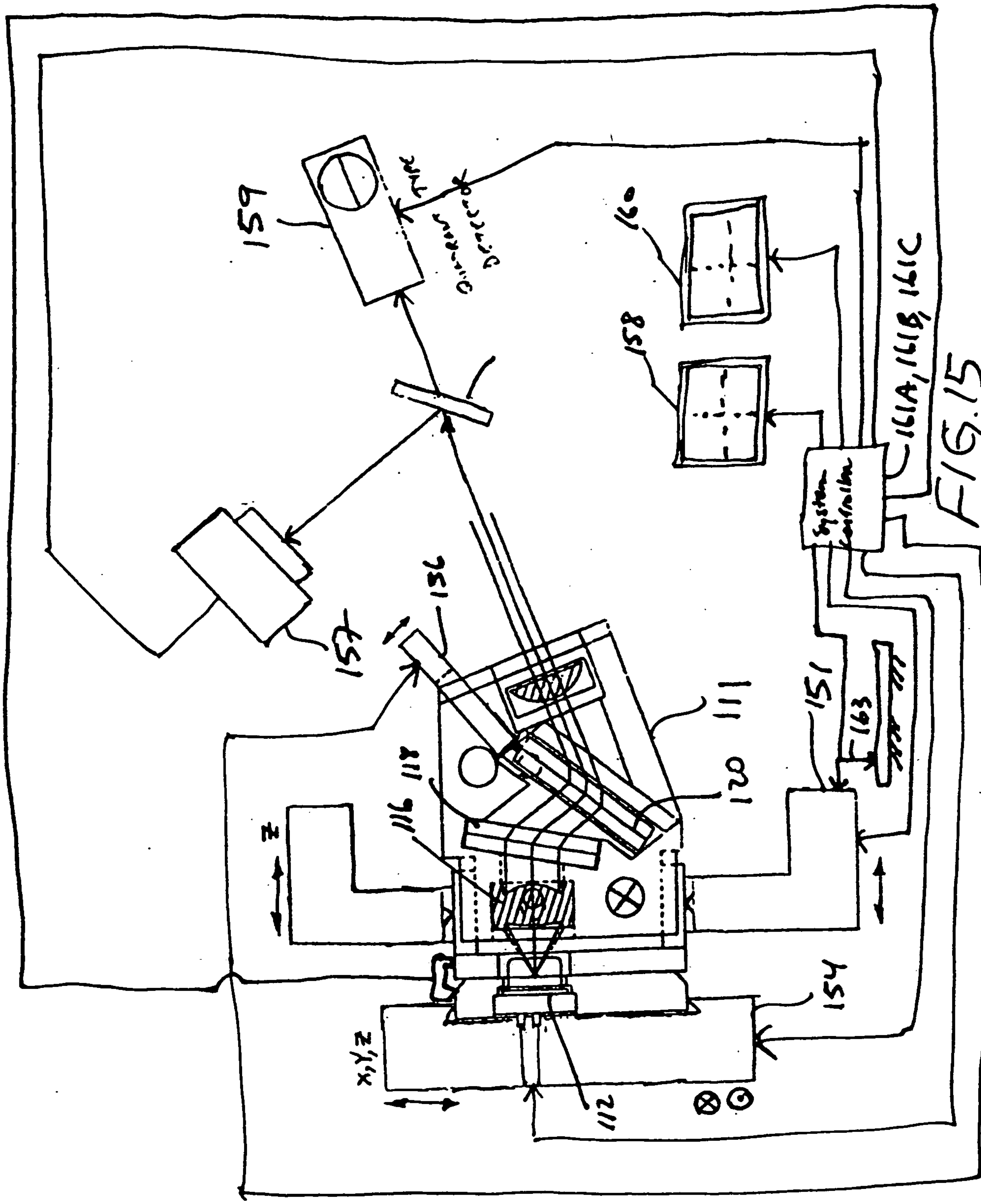

159
157
156
158
160
System Controller
161A, 161B, 161C
111
118
116
120
151
163
154
112
X,Y,Z
Z

FIG.15
(Case B)

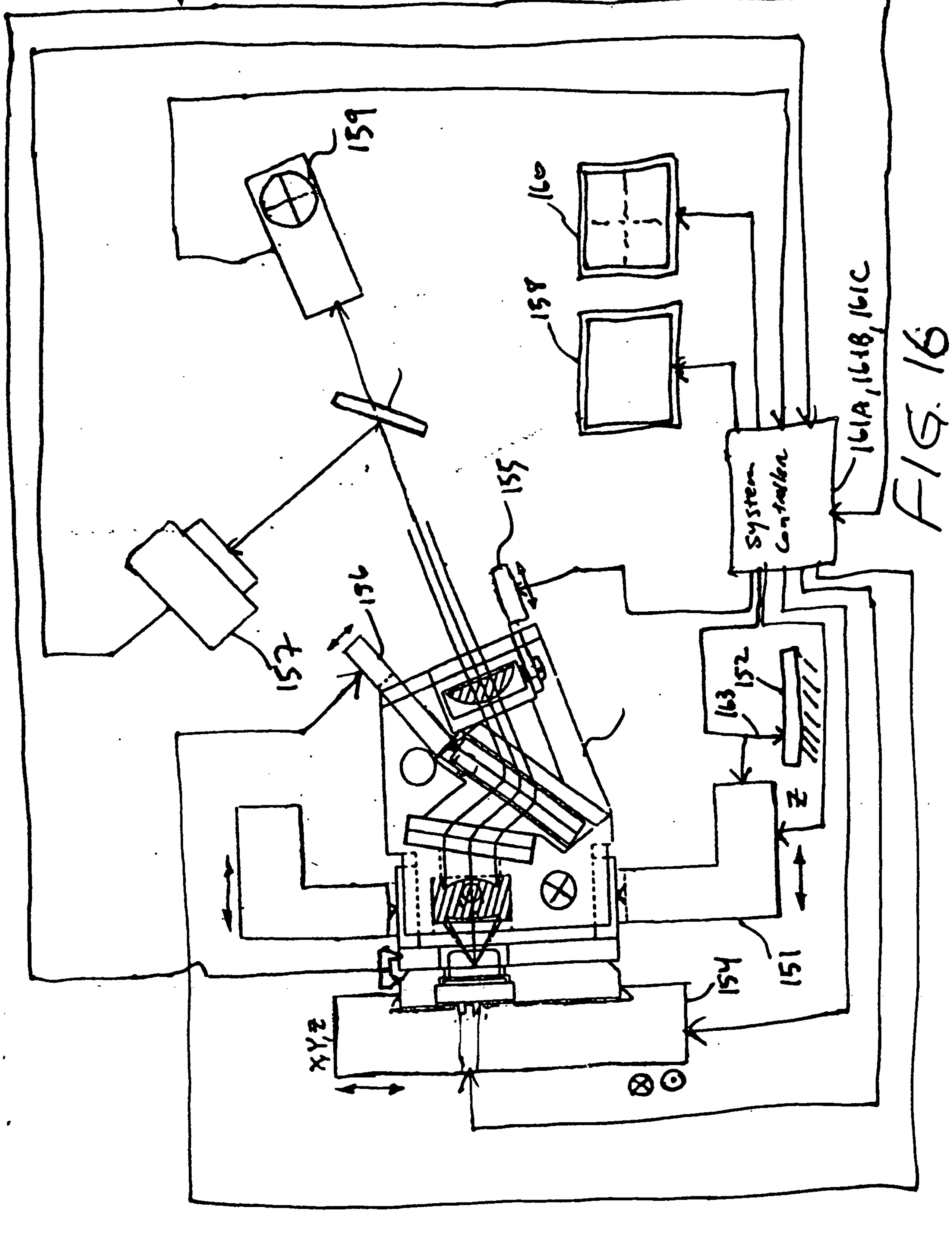

159
160
158
161A, 161B, 161C
System Controller
155
156
157
163
152
Z
151
154
XYZ

FIG. 16
(Case C)

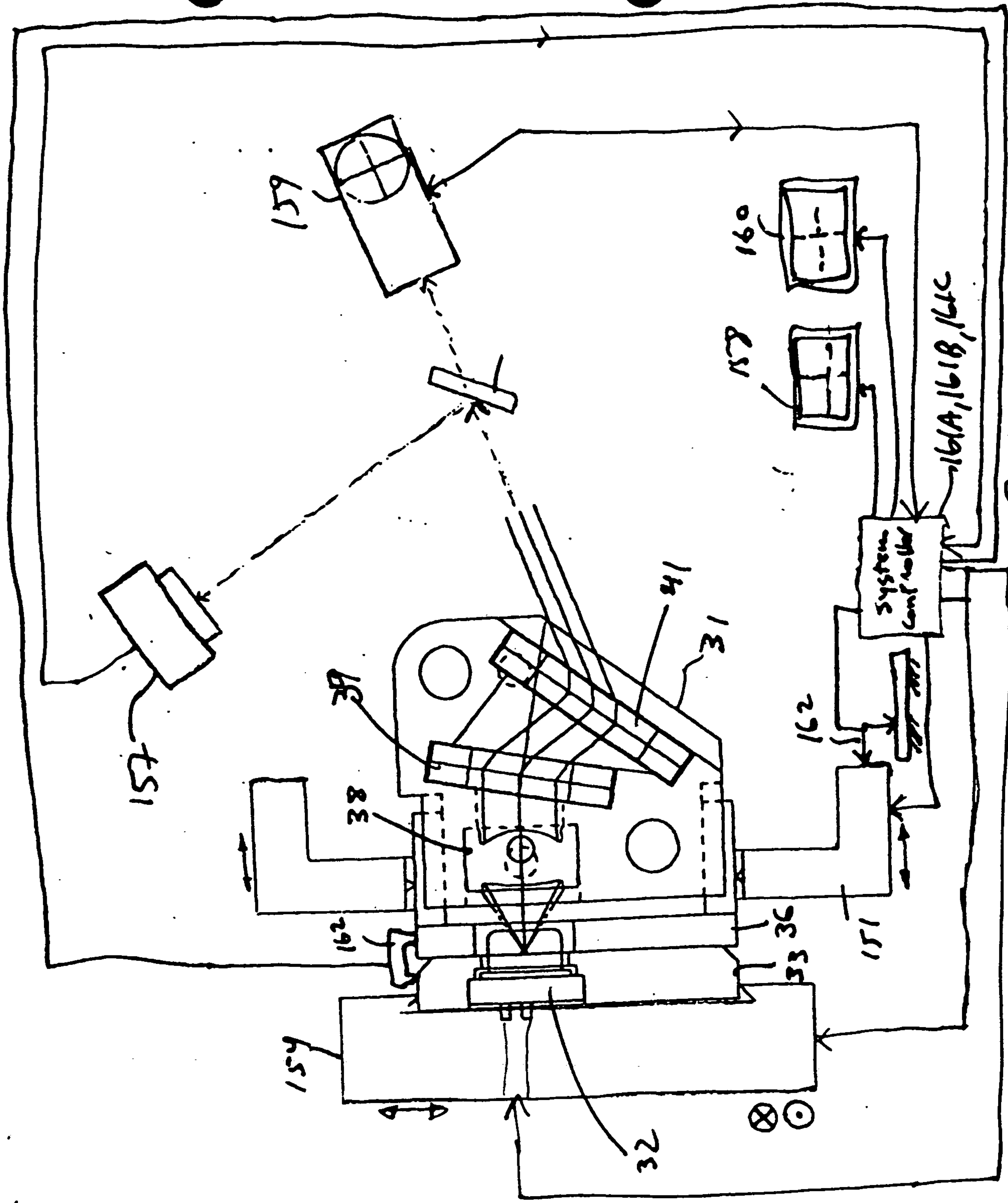
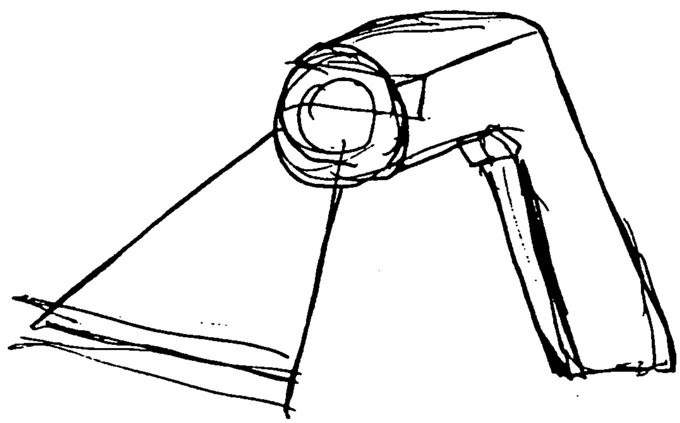

159
160
158
161A, 161B, 161C
System Controller
157
41
31
38
162
36
33
151
154
32

FIG. 17
(Cont'D)



2-D

FIG. 18

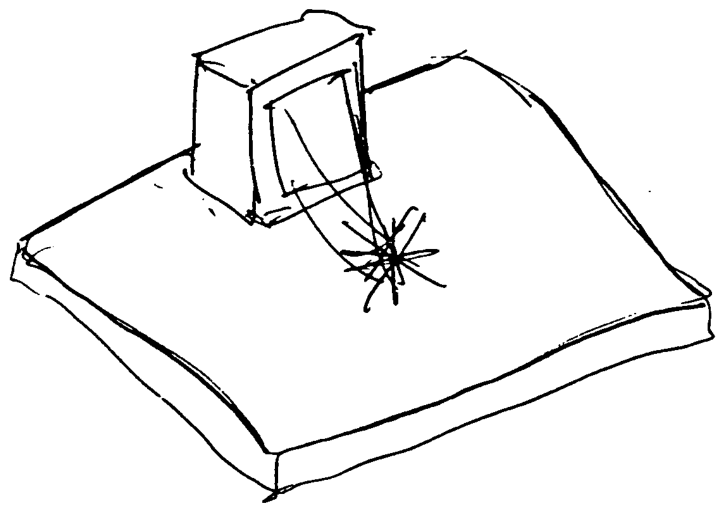


FIG. 19

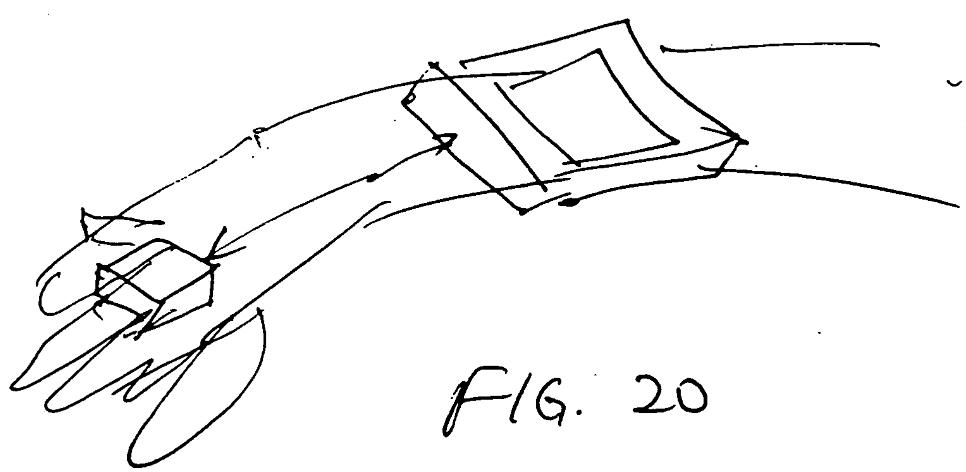


FIG. 20

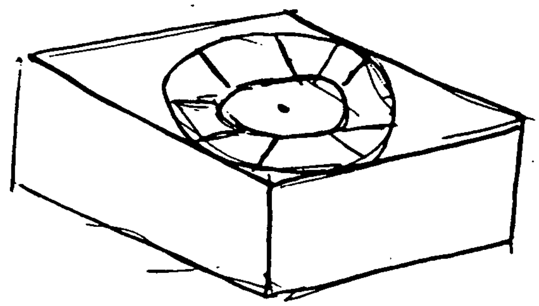


FIG. 21

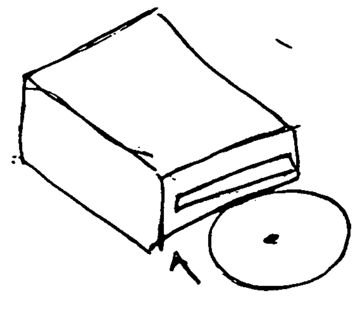


FIG. 22

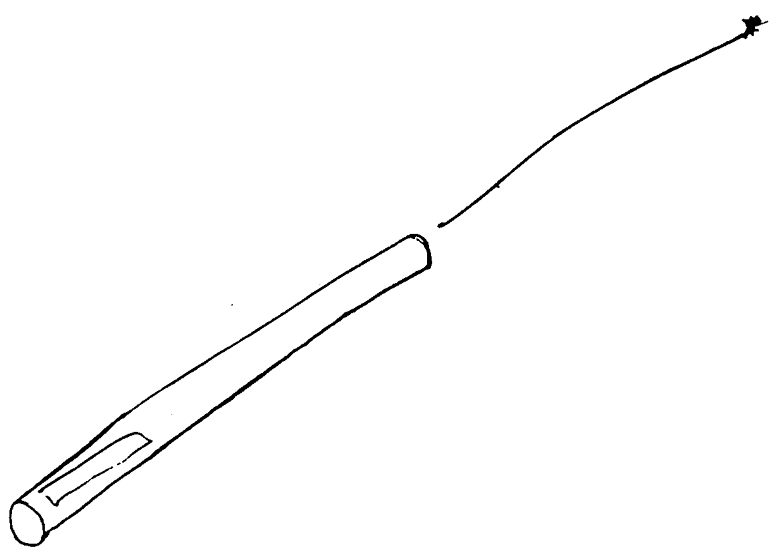


FIG. FIG. 23

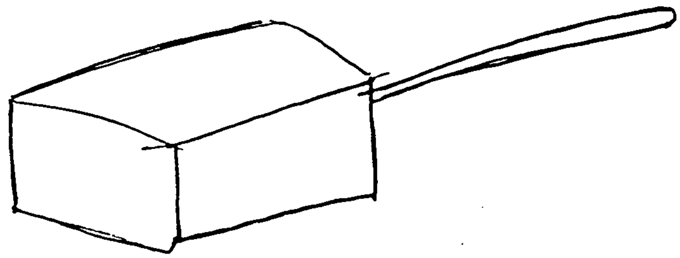


FIG. 24